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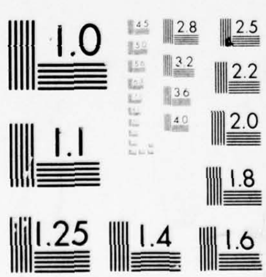

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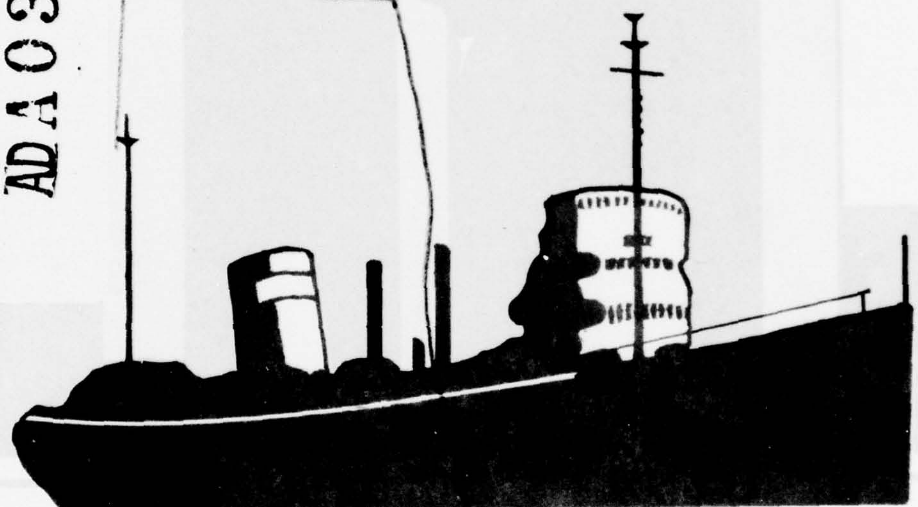

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APPENDIX J.

LAND DISPOSAL.

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The report presents the evaluation of the economic, technical and environmental feasibility of land disposal of dredged material from San Francisco Bay and development of an economic comparison model of various dredging methods and transport modes for different combinations of alternative land and water disposal systems. Studies included costing of dredging equipment and transport modes; mapping potential land sites around the Bay; and evaluating sites in terms of the physical properties of the sediments, site operation and site constraints.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

LAND DISPOSAL OF DREDGED MATERIAL
AND
ECONOMIC COMPARISON OF ALTERNATIVE DISPOSAL
SYSTEMS
DREDGE DISPOSAL STUDY SAN FRANCISCO BAY AND ESTUARY

OCTOBER 1974

U.S. Army Engineer District, San Francisco
Corps of Engineers
100 McAllister Street
San Francisco, California 94102

FOREWORD

In April 1972, the San Francisco District of the United States Army Corps of Engineers initiated a three and one-half year $2.8 million study to quantify the impact of dredging and dredged material disposal operations on the San Francisco Bay and Estuarine environment. The study is generating factual data, based on field and laboratory studies needed for the Federal, State and local regulatory agencies to evaluate present dredging policies and alternative disposal methods.

The study is set up to isolate the questions regarding the environmental impact of dredging operations and to provide answers at the earliest date. The study is organized to investigate (a) the factors associated with dredging and the present system of aquatic disposal in the Bay, (b) the condition of the pollutants (biogeochemical), (c) alternative disposal methods, and (d) dredging technology. The study elements are intended first, to identify the problems associated with dredging and disposal operations and, second, to address the identified problems in terms of mitigation and/or enhancement. The division into separate but inter-related study elements provides a greater degree of expertise and flexibility in the Study.

This report presents the findings of Appendix J, Land Disposal. The overall study will be the basis for preparation of an composite Environmental Impact Statement for Dredging Activities in San Francisco Bay System. A draft final report on the entire study is scheduled for completion in June 1975.

The following is an index of appendices to be published in the Dredge Disposal Study:

APPENDIX	REPORT
	FINAL REPORT
A	Main Ship Channel (San Francisco Bar)
B	Pollutant Distribution
C	Water Column (Water Column - Oxygen Sag)
D	Biological Community
E	Material Release
F	Crystalline Matrix
G	Physical Impact
H	Pollutant Uptake
I	Pollutant Availability
J	Land Disposal
K	Marsh Development
L	Ocean Disposal
M	Dredging Technology

APPENDIX L J - LAND DISPOSAL

INTRODUCTION

The land disposal study is one of three studies which address the feasibility of alternatives to the present system of aquatic disposal in San Francisco Bay waters. The other two alternative studies are concerned with marshland development utilizing dredged sediments and ocean disposal. The overall objective of the Land Disposal Study is to determine the economic, technical, and environmental feasibility of land disposal of dredged material from San Francisco Bay and to develop a useful economic comparison model for land and water alternative disposal systems. The following work items have been performed in keeping with study objectives:

a. Identify potential areas suitable for land disposal of dredged material.

b. Develop a relative cost comparison computer model capable of evaluating the economic efficiency of present dredging operations as well as theoretical alternative dredging and transport systems.

c. Utilizing the cost comparison model, evaluate various alternative disposal schemes which vary with respect to equipment (trailing suction hopper dredge with and without direct pumpout, clam shell, and hydraulic cutterhead dredge), transport mode (hopper direct haul, pipeline and transfer facility, tug and barge), and disposal site (Bay, ocean, intertidal and land).

d. Determine the practicability of the land disposal alternative in terms of environmental advisability, technical feasibility, and economics.

This appendix is not a document for implementing a land disposal system for the Bay Area. It is a feasibility study of land disposal. Inclosure 1 contains a report prepared by the International Engineering Company, Inc. (IECO) under contract number DACW07-73-C-0079 with the San Francisco District, Corps of Engineers. As the work of an independent consultant the findings of this report were not changed materially during the Government reviewing process.

Though the development of cost estimates for dredging equipment was important in the comparison of land and aquatic disposal schemes, these estimates are not a central issue in this report. In the final analysis the report is not concerned with the relative economic efficiency of dredge equipment, but rather, the comparative economics of alternative disposal schemes. However, considering the potential for misuse of the dredge equipment costs and computer model results presented in this report the following discussion is provided

DREDGING EQUIPMENT COST/PRODUCTION ESTIMATES

The great majority of dredging in San Francisco Bay is performed by two trailing suction hopper dredges owned and operated by the Corps of Engineers. These Government plants are not directly comparable to privately owned hydraulic cutterhead and clamshell dredges. Hopper dredges are used for transporting dredged material as well as dredging whereas other dredges require a supporting transport mode. The government plants also have a guaranteed work-load whereas private operators must compete for contracts and may work only a portion of any given year. Hopper production in bank yardage is not usually calculated by the Corps from before and after surveys, but is based upon readings of a yardage meter which is calibrated to reflect the density of the dredge material in the shoal. Material excavated from beyond the limits of the required work, therefore, may still be recorded as pay yardage. Private plants on the other hand are paid upon the basis of detailed before and after dredging surveys. The above factors and others greatly complicate a valid comparison of Government and private dredge equipment production.

The following methods and assumptions were used by IECO in the preparation of dredging equipment hourly costs and production rates for the model study.

a. Hourly Costs.

(1) Trailing suction hopper dredges. Hourly costs for hopper dredges were assumed to be similar to that of the CHESTER HARDING hopper dredge (built in 1939) which is one of the two Government plants operating in San Francisco Bay. Hourly operating costs for the HARDING were determined from the Consolidated Statement of Operations (most recent edition available during preparation of the consultant's report - Fiscal Year 1971) published by the North Atlantic Division of the Corps of Engineers. To calculate the operating costs of the HARDING the "Total Field Expense" was used - that is, the costs for payrolls, subsistence, fuel, plant rental, insurance, attendant plant, and miscellaneous costs. The capitalized first cost for the HARDING based on the salvage value ($2 million) and remaining life (13 years) as well as reported costs for maintenance, repair, and replacement were also used to calculate the total hourly cost of operation. Not included were costs of survey, inspection and supervision, overhead and other indirect costs. Hopper dredge costs were escalated from those shown on the FY 1971 Statement of Operations to present day (1974) costs. A 5,000 hours annual usage was also assumed.

(2) Clamshell and hydraulic dredges. Hourly costs for clamshell and hydraulic dredges were developed based upon various sources of information, dredging contractors and dredge manufacturers. In each case, the hourly costs shown include the capitalized initial cost

(based on a 20-year life a 6-7/8 percent interest rate*), insurance, operating cost, maintenance cost and direct labor. All costs are based on 5,000 hours annual use and include no overhead, or administrative costs.

b. Production Rates.

(1) Trailing suction hopper dredges. Production rates for a representative hopper dredge, the CHESTER HARDING, were taken from the HARDING dredging records. The records (Report of Operations - Hopper Dredges, compiled by the North Atlantic Division of the Corps of Engineers) dated back to 1959. These records showed that the overall average pumping time of the HARDING is 28 minutes, the average dumping time, five minutes, and the average travel speed of the dredge about nine miles per hour. The records showed that the HARDING averaged (weighted in proportion to dredged volume at dredging sites) 2,200 cubic yards of dredged material in its hoppers per trip, but that the actual volume excavated from the bank averaged (also weighted) 1970 cubic yards. The total excavated bank yardage used in the analysis was the sum of the credited (in-place) volume based upon the yardage meter readings plus the estimates of the excess (over-dredging) and the natural shoaling or sloughed material. These figures show that the ratio of hauled yardage to bank (shoal) yardage is about 1.12, or a bulking factor of 12 percent.

(2) Clamshell and hydraulic dredges. In the case of clamshell and hydraulic dredges, equipment characteristics similar to those of available local dredges were assumed while more efficient characteristics were assigned to dredges designated as more tailored to San Francisco Bay conditions. This resulted in a feasible range of productivities for these two types of dredges. Production rates developed for hydraulic and clamshell dredges are assumed to apply only to optimum operating conditions. A study of the shoaling patterns of each site was made to determine reduction factors applicable to each dredge type. Because each machine is capable of covering a particular area each day, a certain depth or cut is required if the dredge is to accomplish its maximum production: the ratio of the actual average depth to the optimum depth is a reduction factor which must be applied to the maximum rate. Additional reduction factors arbitrarily applied included: wedge-shaped, minus 10 percent: spotty or separated shoaling, minus 15 percent: and narrow or restricted work areas, minus 5 percent (for hydraulic dredges only).

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* Development of costs for capital investment features of the various equipment types utilize a discount rate of 6-7/8 percent. Based on the Water Resource Development Act of 1974, PL 93-251, the discount rate for planning Federal water resources developments has been revised to 5-7/8 percent. This reduction will decrease the average annual costs shown in the report for capital investments by about 10 percent. The use of different interest rates do not affect operation and maintenance costs.

The estimates of dredge equipment costs and productivities are necessarily subjective in nature. The altering of one or several of the assumptions made by the consultant could make a significant difference in the resulting figures. For purposes of providing a range of estimates for comparison, the computer model developed by IECO was rerun altering some of the basic assumptions used in the preparation of the report. Table 1 is a summary of the equipment hourly costs and production figures used in the IECO report (Estimate 1) and the figures used for the second comparative model run (Estimate 2). Estimate 2 was prepared in cooperation with the West Coast Dredging Contractors Association.

TABLE 1

HOURLY COSTS AND DAILY PRODUCTION RATES
FOR DREDGING EQUIPMENT

DREDGE TYPE	ESTIMATE 1 * PRODUCTION	ESTIMATE 1 * HOURLY COST	ESTIMATE 2 ** PRODUCTION	ESTIMATE 2 ** HOURLY COST
	1,000 cy/day	dollars	1,000 cy/day	dollars
Hopper dredge				
Bottom dump	31.4	402	27.3	506
Direct pump	37.0	439	32.3	532
Clamshell				
Average plant				
9 cy	6.5	170	7.8	149
13 cy	9.4	195	11.2	165
18 cy	13.0	221	15.6	182
Special plant				
9 cy	7.8	179	___	___
13 cy	11.2	207	___	___
18 cy	15.6	237	___	___
Hydraulic				
Average plant				
16 inch	10.0	157	12.5	146
24 inch	20.0	276	28.1	252
30 inch	30.0	351	44.0	317
36 inch	40.0	384	63.2	346
Special plant				
16 inch	12.5	163	___	___
24 inch	25.0	289	___	___
30 inch	37.0	370	___	___
36 inch	50.0	405	___	___

* ALL EQUIP: Annual Use 5000 hrs
HOPPER (EXISTING): Book Value $2 mill: Remaining Life 13 yrs; & Bulking Factor 12%
CLAMSHELL: (NEW) Book Values $2.1, 2.9, 3.8, 2.5, 3.5, and 4.5 mill: Life 20 yrs
HYDRAULIC: (NEW) Book Values $1.1, 3.0, 4.4, 4.9, 1.3, 3.6, 5.3 & 5.9 mill· Life 20 yrs

** ALL EQUIP: Annual Use 6500 hrs
HOPPER (NEW): Book Value $24 mill; Life 50 yrs, Bulking Factor 25%
CLAMSHELL: (NEW) Book Values $2.5, 3.5 & 4.5 mill: Life 50 yrs
HYDRAULIC: (NEW) Book Values $1.3, 3.6, 5.3 & 5.9 mill: Life 50 yrs

The second estimate increased the cost/production ratio for bottom dump and direct pumpout hopper dredges by 45 and 38 percent, respectively. The cost/production ratios for 9, 13, and 18 cy clamshell dredges on the other hand were reduced 27, 30, and 32 percent. Hydraulic plant (16, 24, 30, and 36 inch) cost/production ratios were similarily reduced by 26, 33, 39, and 43 percent in Estimate 2.

MODEL SENSITIVITY STUDY

Chapter VII of the IECO report presents in detail the seven disposal schemes analyzed by the cost comparison model. For purposes of comparison these seven schemes were reanalyzed using input data compiled in Estimate 2. A complete summary of results of the two computer runs (Run 1 - IECO, Run 2 - Estimate 2) has been included as Inclosure 2 of this appendix.

To provide a basis for comparison of the two computer runs, one set of weighted averages based on average annual volume of material generated at each dredging site were calculated. Table 2 compares the weighted averages of the "Least Cost Only" alternatives for each scheme presented in Inclosure 2. In general, the weighted averages from the two computer runs are comparable.

TABLE 2

WEIGHTED AVERAGES FOR "LEAST COST ONLY" ALTERNATIVES

SCHEMES		RUN 1 ($/cy)	RUN 2 ($/cy)
I	100 Fathom Site	0.78	0.71
II	Petaluma Land Disposal Site	0.81	0.86
III	Sherman Is. Land Disposal Site	0.94	0.95
IV	Closest Aquatic Disposal	0.41	0.44
V	Closest Seaward Aquatic Disposal	0.44	0.44
VI	Compliance w/RWQCB (Bay & Ocean)	0.70	0.65
VII	Compliance w/RWQCB (Bay & Land)	0.73	0.64

The major difference between the two runs was the resulting equipment mix within each scheme. Table 3 is a "Least Cost Only" alternative equipment mix taken from Scheme I of Inclosure 2.

TABLE 3

EQUIPMENT MIX FOR "LEAST COST ONLY" ALTERNATIVES
SCHEME I

DREDGING SITE 1/	RUN 1	RUN 2
1	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline
2	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline
3	18 CY Clam, Bottom Dump Scow, Dump Basin, Fixed Pipeline	18 CY Clam, Bottom Dump Scow, Dump Basin, Fixed Pipeline
4	18 CY Clam, Bottom Dump Scow, Dump Basin, Fixed Pipeline	18 CY Clam, Bottom Dump Scow Dump Basin, Fixed Pipeline
5	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline	Hopper/Direct Pumpout, Bottom Dump Scow
6	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline	18 CY Clam, Bottom Dump Scow
7	18 CY Clam, Bottom Dump Scow Dump Basin, Fixed Pipeline	18 CY Clam, Bottom Dump Scow Dump Basin, Fixed Pipeline
8	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline	18 CY Clam, Bottom Dump Scow
9	Hopper/Direct Pumpout, scow, Dump Basin, Fixed Pipeline	18 CY Clam, Bottom Dump Scow
10	Hopper/Direct Pumpout, Bottom Dump Scow	18 CY Clam, Bottom Dump Scow
11	Hopper/Direct Pumpout, Bottom Dump Scow	18 CY Clam, Bottom Dump Scow
12	Hopper/Direct Pumpout, Bottom Dump Scow	18 CY Clam, Bottom Dump Scow

1/ DREDGING SITES: (1) Suisun Bay, (2) Mare Island, (3) Napa River, (4) Petaluma River, (5) Pinole Shoal, (6) Richmond Long Wharf, (7) San Rafael Cr., (8) W. Richmond Channel, (9) Richmond Harbor, (10) Oakland Harbor, (11) San Francisco, (12) Redwood City.

Scheme I - Run 1 - "Least Cost Only" selected the use of hopper dredges for maximum efficiency in 9 of the 12 dredging sites. On the other hand, Scheme I - Run 2 - "Least Cost Only" designated the 18-cy clamshell dredge as most efficient in 9 out of 12 project areas. This discrepancy was to be expected considering that hopper dredge average costs/cubic yard were increased while clamshell average costs/cubic yard were decreased in Equipment Estimate 2.

Though the model is an effective tool for estimating the relative costs of alternative dredging and disposal schemes, the altering of several parameters in the program may significantly change the ordering and costing of dredging systems equipment. In addition, though all of the equipment combinations discussed in the inclosed report are theoretically feasible, some of the equipment combinations may be impractical from an environmental or technical standpoint.

Utilizing detailed engineering, technical, and environmental information as well as the results of the model study, the inclosed contractor's report addresses the feasibility of land disposal of dredged material in San Francisco Bay.

CONTINUING STUDIES

This appendix represents one of thirteen support or input documents to the Final Report. The appendix is an information document and any comments received will assist in the preparation of the Final Report. In addition, further studies will be conducted with respect to "Land Disposal" and the "Economic Comparison of Alternative Dredging and Disposal Systems" as follows:

a. More detailed environmental analysis of potential land disposal sites.

b. Exploration of the availability of the identified potential land disposal sites.

c. Further use of the computer model for estimating the relative costs of alternative dredging and disposal schemes.

INCLOSURE ONE

TO

APPENDIX J

LAND DISPOSAL OF DREDGED MATERIAL
AND
ECONOMIC COMPARISON OF ALTERNATIVE DISPOSAL SYSTEMS
DREDGE DISPOSAL STUDY SAN FRANCISCO BAY AND ESTUARY

FINAL CONSULTANT REPORT

(INTERNATIONAL ENGINEERING COMPANY, INC.)

U. S. ARMY ENGINEER DISTRICT
SAN FRANCISCO
CORPS OF ENGINEERS

FINAL REPORT

LAND DISPOSAL OF DREDGED MATERIAL AND ECONOMIC COMPARISON OF ALTERNATIVE DISPOSAL SYSTEMS DREDGE DISPOSAL STUDY SAN FRANCISCO BAY AND ESTUARY

MAY 1974

IECO
INTERNATIONAL ENGINEERING COMPANY, INC.
220 MONTGOMERY ST · SAN FRANCISCO · CALIFORNIA

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Exhibit

A controversy has arisen in recent years between environmental and development interests as to the potential adverse effects of present dredged spoil disposal practices on the marine environment of the San Francisco Bay and Estuary. The San Francisco District of the Corps of Engineers, which has the responsibility for the majority of Bay dredging, has embarked upon a comprehensive study of dredging to develop information to assist in resolving the conflict. The purpose of the study is to determine the environmental effects of dredging in San Francisco Bay and Estuary and to investigate modifications and alternatives which may mitigate detrimental effects of current dredging practices.

In this report, which is part of the District's study, one potential alternative to aquatic disposal of dredged material is investigated: land disposal. The objective of the study, as set forth in Schedule "A" of the Scope of Services of Contract DACW 07-73-C-0079, is to determine the (1) economic, (2) technical, and (3) environmental feasibility of land disposal for material dredged from San Francisco Bay, and to develop a useful comparison of alternative land and water disposal systems. To accomplish this objective, studies were required in the two distinct areas of (1) land disposal sites, and (2) dredging and transport systems. Land disposal site studies included the identification of potentially suitable sites, assessment of factors pertinent to their selection, development, and operation, and development of order-of-magnitude costs. An analysis of dredging/transport systems was performed, utilizing a mathematical simulation model programmed for solution on a digital computer, and relative costs of dredging and transportation using various dredging/transport modes and using both aquatic and land disposal sites were determined.

The methodology for the studies was briefly as follows:

- Land Disposal Sites - Working within prescribed parameters (size, elevation, distance, etc.), potential sites were identified through field and office studies and evaluated on the basis of technical, environmental, economic, and administrative factors. The most viable potential sites were displayed graphically and significant factors affecting their feasibility as disposal areas listed. Next, development and operation processes for land disposal sites were outlined. Such items as evaluation of existing

conditions, site preparation, foundation settlement, dike design and construction, separation of solids in a slurry from transporting waters by sedimentation and evaporation, and design of settling ponds were discussed. A study of the placement and processing of slurry in the disposal areas followed, and a section on the hypothetical development of representative sites included. Finally, the subjects of enhancement and future use of disposal sites were discussed.

Early in the study, it was concluded that definitive data on the physical and chemical characteristics of the Bay sediments were lacking; accordingly, a program of sampling and testing of material from the dredging sites was implemented. Included were testing of the engineering properties of the material, settlement tests, chemical testing of the bottom sediments and elutriates, and cation exchange tests. The engineering tests were used in spoil placing and processing analyses, settling tests were used in settlement pond analyses, chemical tests were used when studying the feasibility of discharging supernatant water from settling ponds to adjacent waters, and the cation exchange tests used to determine the suitability of dredged material for agricultural use.

It was determined from the land disposal portion of the study that there are disposal sites within a reasonable distance of dredging sites which meet the established criteria. There are, of course, additional costs associated with land disposal. Costs for developing and operating two of the most likely potential sites, one at the north end of San Pablo Bay near the Petaluma River and the other on Sherman Island in the Sacramento-San Joaquin River delta, are tabulated below:

	Petaluma	Sherman Island
1. Unprocessed Material* Unit site development cost (Includes capital costs of acquisition and development and O&M costs)	$0.19/c.y.	$0.17/c.y.
2. Processed Material** Unit site development cost (Includes costs of (1) plus site preparation and processing costs)	$0.59/c.y.	$0.66/c.y.

*Material placed hydraulically in disposal ponds with no further treatment than decantation of water.

**Material which has, in addition to the above, been improved by mechanical working.

It is possible that the value of a land disposal site could be enhanced because of improved drainage, wildlife habitat or recreational potential, or agricultural or industrial use, and the cost of development offset. This possibility was not explored quantitatively in this study, however.

- <u>Alternative Disposal Systems</u> - A comprehensive study of the equipment required to remove and transport dredged material from dredging to disposal sites was made. Various types of dredges (clamshell, hydraulic, and hopper) were studied in detail and production rates and costs developed. Three basic modes of transport: the hopper dredge, tugs and scows, and pipelines, were considered and production rates and costs established. Finally, a study of transfer equipment, i.e., equipment used to change transport modes, was made, and conceptual designs and costs developed. Three basic types of transfer stations were studied: the first a barge-mounted unit including pumping and other facilities, the second a fixed installation in San Pablo Bay, and the third a fixed installation at a land disposal site.

A cost comparison model was developed to compare alternative dredging/transport systems. Using input data on dredging and disposal sites as well as characteristics and costs of dredging, transporting, and transfer equipment, the model simulated various alternative disposal systems and computed costs for each. The least cost alternatives were tabulated and shown graphically.

Seven disposal schemes, defined by disposal sites, were analyzed. The schemes and their costs are tabulated below:

Scheme	Description	Least Cost (Average)
I.	Aquatic Disposal - 100 Fathom Line	\$0.78/cy
II.	Land Disposal - Petaluma	\$0.81/cy
III.	Land Disposal - Sherman Island	\$0.94/cy
IV.	Aquatic Disposal - Closest	\$0.41/cy
V.	Aquatic Disposal - Closest Seaward	\$0.44/cy
VI.	Aquatic Disposal - RWQCB Criteria	\$0.70/cy
VII.	Land and Aquatic Disposal - RWQCB Criteria	\$0.73/cy

The costs do not include overhead, supervision or profit.

It was found from the analysis that the most economical dredging machine was the hopper dredge, followed by the large capacity clamshell dredge. For short hauls, it was determined that the bottom-dump hopper dredge was the most economical mode of transport. For longer hauls, if a fixed pipeline was included in the system, it was found to be the most economical. For other long hauls, a tug-scow combination was found to be the least costly transport mode.

The following general comments and conclusions pertaining to the study are offered:

From the outset, it was recognized that very little information was readily available on the subjects to be studied. Many assumptions regarding the subjects of dredging, transport operations and site development were made and incorporated into the studies and, consequently, into the factors which assist in defining the feasibility of land disposal. Future studies and experience may alter or verify the assumptions made in this report.

Under certain conditions, large-scale land disposal of dredged materials is feasible when compared with current aquatic disposal practices. The main conditions are (1) that financing is available to capitalize an undertaking of this magnitude, including the acquisition and development of suitable land disposal sites and the acquisition of equipment required to transport and distribute dredged material to the sites, and (2) that a centralized permitting and authorizing organization is established to sequence and control dredging for maximum utilization of necessary common facilities.

CHAPTER I

CONCLUSIONS

CHAPTER I

CONCLUSIONS

1.1 GENERAL

This report represents an initial in-depth survey and determination of factors affecting the feasibility of land disposal of dredged materials from San Francisco Bay. Given all the technical, environmental, economic and administrative factors identified in the following chapters, it is still very difficult to reach a decision concerning the feasibility of land disposal for several reasons. First, feasibility must be defined in relative terms; many reference bases exist which may be used. Second, the value or weight attached to any factor or group of factors is open to subjective interpretation. Third, because of the initial study nature of this report, many of the factors which significantly affect feasibility are based on assumptions which may be challenged, modified, or verified in the future.

1.2 SUMMARY OF PERTINENT FACTORS

- Technical - There are apparently no insurmountable technical problems associated with land disposal. It must be realized that considerable engineering work must be accomplished to develop and implement the operation of a land disposal site as well as to develop the new and innovative dredging/transport systems which will yield low cost operations.

- Environmental - The scarcity of information regarding the environmental effects of both land and aquatic disposal of dredged material renders environmental factors difficult to quantify and relate to other factors. Consideration of environmental effects and potential uses of operational and completed land disposal sites involves many intangible and indeterminate factors; the importance of these factors will undoubtedly be relative to a variety of viewpoints.

A number of environmental considerations regarding land disposal are subject to specific regulations. It is important to recognize that should certain of these regulations change, such as the Environmental Protection Agency's dredged material disposal criteria, the feasibility of land disposal may be significantly affected. Regulations concerning the quality of effluent water from land disposal site operations must be met; it appears that they most likely can. It is anticipated that noise and air pollution standards can also be met. It appears probable that neither ground water nor surface water quality need be impaired by land disposal.

Other environmental considerations which must be taken into account include the aesthetic impact of the disposal area and its effect on the adjacent wildlife communities. These factors will require special consideration and possible mitigation measures.

The ultimate use of a completed site may provide incentives to land disposal because of enhancement, such as increased flood protection, recreational or wildlife habitat potential, and agricultural or industrial use. Quantitative evaluation of such factors is difficult without future study.

- Economic - The economics of land disposal are easily subjected to rational analysis. However, the factors determined from such analyses are only as accurate as the information and assumptions used in their formulation. Changes in the availability and costs of goods and services, interest rates and land values assumed in economic analyses performed in this study will significantly affect land disposal feasibility.

A summation of basic development and operation costs (without markups) indicates that compliance with the Regional Water Quality Control Board's current dredge disposal policy would cost \$0.70 per cubic yard of dredged material for disposal at approved aquatic sites, while disposal at the Petaluma land disposal site would cost \$0.81 per cubic yard (\$0.62 for dredging and transport, \$0.19 for site development and operation). However, there are many other factors involving economics which will raise

the land disposal cost an indeterminate amount. An effort involving many people as well as a considerable capital outlay will be required to acquire and develop land sites. Development of equipment which will allow low cost operations will also require significant capitalization and work effort. Land disposal economies result from the use of common facilities with inflow to the system at as uniform a rate as possible. Dredging operations must be sequenced and controlled to accomplish this, which will also require additional funding. On the positive side, it is quite conceivable that if certain of the site enhancement techniques discussed in this report are implemented, there may be an appreciation in land value at the disposal sites which will offset the costs of development and operation. Environmental and aesthetic advantages may also accrue from site enhancement.

- Administrative - Administrative policies which affect land use are often dynamic; they reflect current trends and are subject to frequent change, re-evaluation and interpretation. An evaluation of the operation and future use options of potential land disposal sites in the light of existing land use policies indicates that such use will probably be compatible.

1.3 FEASIBILITY

As a result of the initial study efforts of this and preceding reports, it can be concluded that land disposal of dredged material is conditionally feasible. A closer estimate of the feasibility will only be possible after a specific site and a definite group of dredge/transport systems are selected and evaluated in detail. The main conditions are that:

- Sufficient capital will be available to buy or lease land disposal sites and to construct the transport and distribution systems which will allow greatest economies.

- Dredging is controlled and sequenced by a central organization so that the greatest efficiency in the use of common facilities may be realized.

CHAPTER II

INTRODUCTION

CHAPTER II

INTRODUCTION

2.1 BACKGROUND

The economy of the San Francisco Bay area, much of Northern California, and to some extent the rest of the nation, is closely tied to the shipping industry, which transports approximately 60 million tons of raw and manufactured materials into and out of the Bay Area. If this traffic is to continue, it is essential that the harbors, ports, anchorages, and Bay channels be maintained at a great enough depth to accommodate the thousands of vessels which use them. In addition, access to the numerous military installations in the Bay must be maintained by dredging.

The sediments which are deposited in the Bay are largely those washed from dry land upstream, carried in suspension by the rivers leading to the Bay and precipitated in the saltier water of the Bay. The volumes of sediment are not as heavy as they were when hydraulic mining was prevalent in the Sierras, but they are still great enough to pose continuing problems. Maintenance dredging in the Bay is required to maintain some 200 miles of deep water channels, 300 miles of shallow water channels, 50 major ports and anchorages and numerous smaller harbors, marinas and private docks. Most of the dredging is done by the Corps of Engineers and the Navy with the remainder being accomplished by ports and private contractors. The average amount of maintenance dredging now done by and for the San Francisco District of the Corps is some 7 million cubic yards per year. In addition, each year the Corps is responsible for a substantial amount of dredging for new channels and harbor deepening.

In recent years, concern has grown over the impact of dredging and disposal operations on the marine environment. Much of the concern over the dredging process itself is related to the potential effects on marine organisms during the excavating operation; concern over the process of aquatic disposal of dredged material is related to potential effects on water quality and aquatic organisms, including such factors as in-

creased turbidity, covering bottom-dwelling organisms, changes in marine life habitat and the effect of pollutants on marine life. These concerns are evidenced by many laws, regulations and policies regarding dredging.

2.2 SAN FRANCISCO DISTRICT DREDGE DISPOSAL STUDY

Information on the effects of dredging on the marine environment is incomplete, and, since the Corps of Engineers has the responsibility for a majority of the dredging done in the San Francisco Bay, the San Francisco District of the Corps has undertaken a $2.4 million environmental study of dredging. The study will identify the significant environmental impacts associated with dredging, evaluate dredging technology and study measures to eliminate or mitigate identified problems. The scope of the study includes investigations of:

- The effect of the present system of aquatic disposal
- Alternative disposal methods
- Condition of pollutants
- Dredging technology

2.3 LAND DISPOSAL STUDY

This report concerns one of the alternative disposal methods, that of land disposal. Objectives of this report include: (1) identification and evaluation of land sites potentially available for disposal of dredged material and (2) development of a mathematical dredging/transport simulation model which can be used to compare alternatives.

It is generally agreed that many problems must be overcome before land disposal can be used on a large scale. The intent of this report is to present as many of the relevant factors as possible so that decisions concerning the feasibility of land disposal may be made. The relevant factors have been separated into four categories, technical,environmental,

economic, and administrative, which cover the two areas of concern, dredging and transportation, and land disposal itself. Studies of the first objectives, identification and evaluation of land disposal sites, included all four categories of factors while the emphasis on the second objective, dredging and transportation, was primarily economic.

The organization of the report is briefly summarized below:

- Chapter III: dredging sites are described and the quantities and characteristics of the dredged material tabulated.

- Chapter IV: equipment used in the dredging and transportation operations is described. Equipment includes dredges of various types, transport equipment and transfer equipment.

- Chapter V: aquatic disposal sites are described and constraints on their use discussed.

- Chapter VI: identification and evaluation processes for land disposal sites are outlined, the most favorable sites are displayed and the development and operation of the sites is discussed.

- Chapter VII: the mathematical dredging/transport simulation model is described, including the development of input data for the model, the operation of the model itself, and the results of the computer analysis. The results are displayed in tabular and graphic form.

CHAPTER III

DREDGING SITES

CHAPTER III

DREDGING SITES

3.1 GENERAL

Twelve dredging sites in San Francisco Bay, identified in the Scope of Services, were studied. Many of these sites include several individual dredging projects. For example, the Oakland dredging "site" encompasses both Oakland Inner and Outer Harbor Channels, the Port of Oakland berth dredging, Oakland Naval Supply Center Channel and berthing areas, Alameda Naval Air Station, and other dredging projects in the area. The locations of the twelve dredging sites are shown on Plate III-1.

Anticipated annual quantities of material to be dredged from each of the twelve sites during the 20-year period of this study are shown in Table III-1. These quantities were developed from historical dredging records and other available information on each dredging site and include all significant Bay dredging projects, public and private.

Dredging at some sites is required on an annual basis while it is less frequent at others. The frequency of dredging, as shown on Table III-1, is dependent on the local shoaling rate and the demands of shipping on the channel or berth facility.

Quantities of dredged materials during the 1975 -1980 period are higher than comparable later periods because they include authorized or imminent new work in addition to normal maintenance dredging.

3.2 DREDGED MATERIAL CHARACTERISTICS

The majority of the sediments to be dredged at the prescribed sites can

be described as "bay mud". Bay mud generally consists of soft, plastic, black-to-grey silty clay, clayey silt, minor organic material and clayey fine-grained sand, resulting largely from flocculation in salt water. Clay-sized particles include 45 to 90 percent of the material; this fraction consists of about one-third montmorillinite, one-third normal and hydrated mica, and one-third mixed layered montmorillinitic, chloritic and kaolinitic materials.

Although the chemical and physical characteristics of bay mud are fairly well documented, it was decided early in the study that further information on the sediments at specific sites would be required to assist in determining landfill feasibility. In particular, it was found that there was a paucity of information available on sediment elutriates, cation exchange properties of sediments, and settling data. Accordingly, a sampling and testing program was initiated which is described below.

Ten representative areas were sampled: San Francisco, Redwood Creek, Oakland Outer Harbor, Richmond Harbor, San Rafael Creek, Pinole Shoal, Mare Island, Suisun Bay, Napa River and Petaluma River. The samples were collected with a 3-inch diameter plexi-glas lined coring tool. Determinations of wet unit weights were made on the research vessel; water contents were calculated later. Samples were delivered to laboratories for determination of chemical and engineering properties. The sampling was performed by the CSO Laboratory of Concord, California.

It was found that the apparent (in situ) densities of the samples varied from 1.30 gm/cc (83.5 lbs/cf) to 1.64 gm/cc (105.4 lbs/cf) and the water contents from 41.3 to 172.0 percent. As would be expected, the samples from the upper part of the area (Suisun Bay, Pinole Shoal, and Napa River), were found to be more sandy than those from the lower part of the Bay. The field data from the sampling program are included in Appendix A .

Settlement tests were conducted to determine the settling times of dredged material when hydraulically placed in a land containment area. This information is vital to effluent water quality considerations in site design and operation. The settling tests were performed under the direction of Prof. Ray Krone at the University of California at Davis. The tests and their application are described in Chapter VI; test data are included in Appendix D.

Prof. Krone also provided comments on the separation of solids from transporting waters (Section 6.3.6).

Chemical testing was performed by Environmental Quality Analysts, Inc., of San Francisco. Specifications for the chemical tests are as follows:

- Bottom sediment analyses - as specified by EPA for mercury, zinc, cadmium, lead, and oil and grease.
- Elutriate analyses - as specified by the tentative method prepared by EPA Region IX, using separately for each sample:
    a. seawater
    b. San Francisco tap water

In addition to the analyses indicated above, the filtered elutriate was analyzed for dissolved mercury, cadmium, lead, zinc, and BOD.

- Cation exchange tests - These tests involve displacing exchangeable metals with ammonium ion, following the method of Chapman, followed by atomic absorption spectrophotometric determination of the displaced cations sodium, potassium, calcium, magnesium, cadmium, mercury, zinc and lead.

The results of the chemical testing are tabulated in Appendix B. They were used by Professors Krone and Delwiche in their analyses (Section 6.3 and 6.4).

Engineering tests were performed by the Harding Lawson Associates Laboratory in San Rafael. The tests included:

- Atterberg Limits

- Moisture content/dry density
- Unconfined compression
- Particle size analyses
- Consolidation
- Compaction

The results of the testing are given in Appendix C.

The Harding-Lawson Associates also provided advice on site preparation and slurry processing (Chapter VI).

Additional material characteristics as they relate to site operation are discussed in Chapter VI.

3.3 DREDGING SITE CHARACTERISTICS

Characteristics peculiar to each site which affect dredging operations include shoaling patterns as well as rates and restrictions such as high vessel traffic or narrow channels. These characteristics influence the productive rates of dredges and the choice of dredge size and type.

Site characteristics were studied using sounding sheets and local maps. Characteristics for each site were generalized as follows:

Site	Shoaling Depth	Coverage	Work Area	Avg Face Depth
Suisun Bay	Uniform	Spotty	Open	3 Ft
Mare Island	Wedge	"	"	5 Ft
Napa River	Uniform	"	Narrow	3 Ft
Petaluma River	Wedge	Smooth	"	2½ Ft
Pinole Shoal	Uniform	Spotty	Open	4 Ft
Richmond L.W.	Uniform	Smooth	"	3 Ft
San Rafael Cr.	Uniform	"	Narrow	3½ Ft

Site	Shoaling Depth	Coverage	Work Area	Avg Face Depth
W. Richmond Ch.	Wedge	Smooth	Open	3 Ft
Richmond Hbr	Uniform	"	"	3 Ft
Oakland	Wedge	Spotty	"	3 Ft
San Francisco	Wedge	Smooth	Narrow	3 Ft
Redwood City	Wedge	"	Open	3 Ft

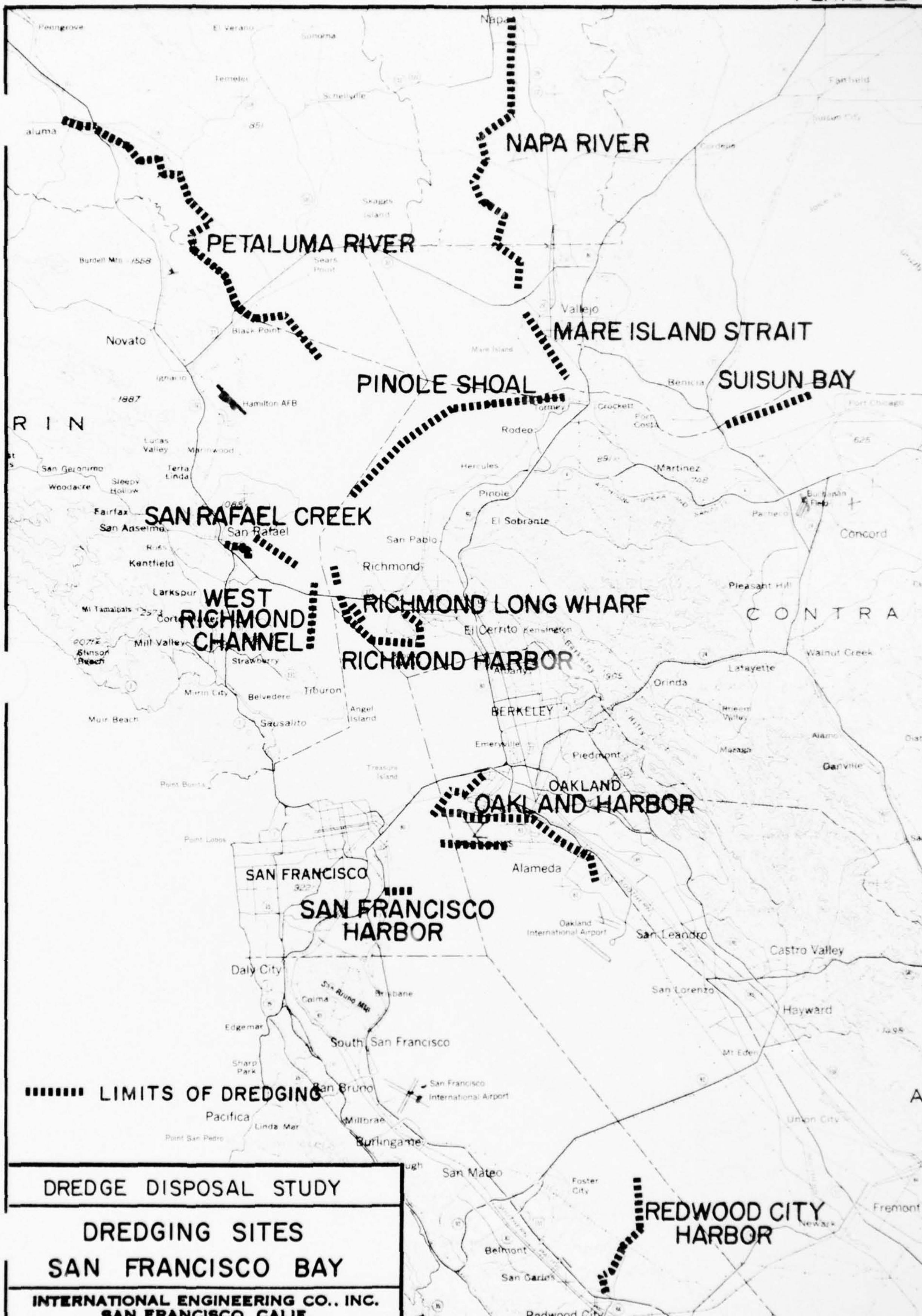
These characteristics were used in determining dredge productivity which is discussed in Chapter IV.

PROJECTED ANNUAL VOLUMES OF DREDGING
(1000 Cubic Yards)

Dredging Site	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Total
1. Suisun Bay	1080	1080	1080	1080	1080	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	8,850
2. Mare Island	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	3050	61,600
3. Napa River			840												840						1,680
4. Petaluma River	580				230				230				580				230				1,850
5. Pinole Shoal	3008	3008	3008	3008	3008	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	36,040
6. Richmond Long Wharf	1130	1130	1130	1130	1130	460	460	460	460	460	460	460	460	460	460	460	460	460	460	460	12,550
7. San Rafael		240								240								240			720
8. W. Richmond Channel	762	762	762	762	762	340	340	340	340	340	340	340	340	340	340	340	340	340	340	340	8,910
9. Richmond & Pt. Molate	856	849	535	1126	535	849	535	805	535	1170	535	805	856	849	535	1126	535	849	856	605	15,546
10. Oakland	1472	1924	1952	1924	1952	1924	1952	1924	1952	1924	1952	1924	1952	1924	1952	1924	1952	1924	1952	1924	38,280
11. San Francisco	650	600	700	600	700	600	700	600	700	600	850	600	700	600	700	600	700	600	700	600	13,100
12. Redwood City	1026	576	576	576	576	1026	576	576	576	576	1026	576	576	576	576	1026	576	576	576	576	13,520
TOTAL	13,614	13,219	13,633	13,256	13,023	9,879	9,243	9,385	9,473	9,990	9,843	9,385	10,144	9,429	10,083	10,156	9,473	9,669	9,564	9,385	211,846

Total for 20 year period = 211,846,000 cubic yards

TABLE III - 1



DREDGE DISPOSAL STUDY

DREDGING SITES
SAN FRANCISCO BAY

INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.

CHAPTER IV

EQUIPMENT

4.1 GENERAL

Equipment required to remove and transport dredged material from dredging to disposal sites is discussed in this chapter. The type of equipment selected affects the characteristics of dredged material delivered to a disposal site and the duration, cost, and feasibility of a dredging project. Conversely, dredging and disposal site characteristics affect equipment selection.

In the study, innovative new concepts in equipment were introduced in addition to conventional equipment for comparison purposes. These new concepts, primarily derived from materials handling technology in other fields, have never been tried in practice but appear promising if developed and employed.

It is important to understand the relationships between and restrictions on equipment types. Equipment used to dredge material from a channel bottom and transport it to a disposal site essentially comprises a materials handling system that may consist of a single piece or several pieces of equipment. If the system involves several pieces, each must be compatible with the others.

Equipment compatibility within a system renders the evaluation and comparison of system elements meaningless. For instance, a realistic comparison of transportation elements alone cannot be made without examining the operating characteristics of the particular dredges which would complete each system. A hopper dredge can both dredge and transport material itself; since the dredging operation can affect the characteristics of the material, the unit transportation cost is dependent on the dredge. Similarly, tug and barge transportation cycle times and pipeline characteristics are dependent on the sizes and production rates of dredges with

which they are used. For this reason, various compatible dredge and transportation systems were included for economic analysis in the dredge simulation model discussed in Chapter VII.

Equipment is grouped into functional categories including dredging, transportation and transfer elements. Transfer equipment may be used to change a transport mode or to transfer dredged material from a dredge to a transport mode.

4.2 DREDGING EQUIPMENT

4.2.1 General - Dredges remove material from the bottoms of water bodies either by mechanical or hydraulic action or by a combination of the two. Many various forms of dredges are in use today: clamshell, trailing arm or hopper, suction head hydraulic, cutterhead hydraulic, bucket line, and dipper. The clamshell, hopper and suction head hydraulic were selected for inclusion in this study as the most efficient for the San Francisco Bay area while the others were rejected for reasons stated in Section 4.2.5.

The rate at which a dredge excavates material is dependent upon site, equipment and operating conditions. Site conditions include material characteristics, depth of face, spacing of dredging areas, shape of dredging areas, and channel restrictions. Equipment conditions include such things as size, type, condition, horsepower, moving speed, bucket shape, draghead shape, heaping characteristics and bucket or ladder moving speed. Operating conditions include operator efficiency (speed, overlap, etc.), wind, waves and weather. Almost all dredges are built to operate under specific conditions. The productivity of a dredge is difficult to predict and may vary widely depending on the above-listed conditions.

Since production rates define unit costs, many assumptions were made regarding the above variables in an attempt to estimate production rates as relatively as possible. It was always assumed that reasonably efficient operators would be available and that material characteristics (refer to Chapter III) were always the same. In the case of clamshell

and hydraulic dredges, equipment characteristics similar to those of available local dredges were assumed while more efficient characteristics were assigned to dredges designated as more tailored to San Francisco Bay conditions. This resulted in a feasible range of productivities for these two types of dredges. It may be, however, that dredging technology will produce dredges capable of far exceeding the ranges of productivities used in this study. No such range is given for the hopper dredge used in this study because it is one of the most efficient of all dredges.

Production rates developed for hydraulic and clamshell dredges are assumed to apply only to optimum operating conditions. A study of the shoaling patterns of each site was made to determine reduction factors applicable to each dredge type. Because each machine is capable of covering a particular area each day, a certain depth or cut is required if the dredge is to accomplish its maximum production; the ratio of the actual average depth to the optimum depth is a reduction factor which must be applied to the maximum rate. Additional reduction factors arbitrarily applied included: wedge-shaped shoaling; minus 10%; spotty or separated shoaling; minus 15%; and narrow or restricted work areas; minus 5% (for hydraulic dredges only).

Production rates for a representative hopper dredge, the CHESTER HARDING, were taken directly from the HARDING's dredging records.

Estimated production rates for the three types of dredges are tabulated in Table IV-1. Two production rates are shown for clamshell and hydraulic dredges to reflect the productivity range described above. Production rates of hopper dredges are not directly comparable with those of other dredges since hopper dredges are used for transporting as well as dredging. For comparison purposes, in this table an assumed travel time of one hour was added to the bottom dump hopper dredge cycle (load, turn, unload) time to establish a daily production rate; the cycle for the direct pumpout hopper dredge was assumed to consist of loading and pumpout only. In the cost comparison computer model, of course, dredging and transportation times are computed for each individual case.

The costs associated with purchase and operation of dredges vary according to individual dredge designs. Average costs for each type of dredge were developed, based on numerous sources of information. In each case, the hourly costs shown include the capitalized initial cost (based on a 20-year life at 6-7/8% interest), insurance, operating cost, maintenance cost and direct labor. All costs are based on 5000 hours annual use and include no overhead, administrative costs or profit.

4.2.2 Hopper Dredges - The hopper dredge is a self-propelled ocean going vessel which removes material from the bottom of the bay or ocean by scraping and sucking through pipes known as drag pipes, which are trailed on the sides of the vessel. The material being dredged enters the drag pipes through drag heads, which are vacuum cleaner-like attachments at the ends of the drag pipes. The dredged material is pumped into bins or hoppers in the vessel, from which it can be discharged either by bottom dumping or by direct pumpout.

Hopper dredges in the United States are owned and operated by both private contractors and government agencies. A large fleet is owned by the Corps of Engineers for use in meeting their dredging commitments throughout the country. For purposes of this study the dredge CHESTER HARDING, owned and operated by the Portland District of the Corps of Engineers, was chosen for analysis. The HARDING spends a large percentage of its operating time in the San Francisco Bay area and it appears to be one of the more efficient of the large capacity hopper dredges owned by the Corps. Also, long term records are available on the HARDING's performance in the Bay.

The HARDING, built in 1939, is 308 feet long, 56 feet wide, and has a maximum draft of twenty feet eight inches. The hoppers (total capacity 2682 cubic yards) are filled by pumping through two 22-inch diameter drag pipes - one on each side of the ship - each utilizing a 1000 horsepower pump.

CORPS OF ENGINEERS - HOPPER DREDGE CHESTER HARDING

The operating characteristics of the HARDING were determined by analysis of dredging records (Report of Operations - Hopper Dredges, compiled by the North Atlantic Division of the Corps of Engineers) dating back to 1959. These records showed that the overall average pumping time of the HARDING is 28 minutes, the average dumping time 5 minutes, and the average travel speed of the dredge nine + miles per hour. The records showed that the HARDING averaged (weighted in proportion to dredged volume at dredging sites) 2200 cubic yards of dredged material in its hoppers per trip, but that the actual volume excavated from the bank averaged (also weighted) 1970 cubic yards. Bank yardage is not usually calculated by the Corps from before and after surveys, but is based upon readings of a yardage meter which is calibrated to reflect the density of the dredged material in the shoal. This density is periodically checked by sampling of the shoal. The total excavated bank yardage used in our analysis was the sum of the credited (in-place) volume based upon the yardage meter readings plus the estimates of the excess (over - dredging) and the natural shoaling or sloughed material. These figures show that the ratio of hauled yardage to bank (shoal) yardage is about 1.12, or a bulking factor of 12 percent. Other authorities estimate the bulking to be 20 percent or much greater. Bulking is a function of the consolidation in the hopper and the amount of material allowed to overflow the hoppers. The effect of overflowing is the subject of considerable controversy and has a great bearing on the efficiency of the hopper dredge operation.

The San Francisco District is presently conducting a study to more accurately determine the actual volume of shoal material excavated by the HARDING.

For the purposes of this study, it was assumed that for each dredging site, the bank volume dredged by the HARDING was the average noted in the dredging records, i.e., the total of credited yardage, excess yardage, and natural shoaling.

As noted above, hopper dredges can be emptied either by bottom dumping or by a direct pumpout to a pipeline or into a scow. Hopper dredges with direct pumpout capability have been used for many years in the Philadelphia District of the Corps of Engineers (Ref. 55*) and elsewhere.

* See Appendix F - Bibliography

Several more of the Corps' hopper dredges are programmed for conversion to direct pumpout. The Plant Replacement and Improvement referred to in Ref. 7 shows the HARDING scheduled for this modification in 1971-74 at a total cost of $2,000,000. Although this modification has not taken place, the $2,000,000 figure was used in calculating the capital cost of a hopper dredge with pumpout capability for use in the computer model (Chapter VII).

Operating costs for the HARDING were determined from the Consolidated Statement of Operations (most recent edition available - Fiscal Year 1971) published by the North Atlantic Division of the Corps of Engineers. Tc make a valid comparison between the operating costs of the HARDING and those of other types of dredges, only the "Total Field Expense" was used - that is, the costs for payrolls, subsistence, fuel, plant rental, insurance, attendant plant, and miscellaneous costs. Not included were costs of survey, inspection and supervision, overhead and other indirect costs.

Hopper dredge costs were escalated from those shown on the FY 1971 Statement of Operations to present day (1974) costs rather than to the 1975 base specified in the Scope of Services because of uncertainties in attempting to forecast the 1975 costs of fuel and other energy-related items. The same rationale was used for all other costs in the study. It is felt that a valid comparison of costs can be made by using 1974 costs; also, the cost comparison computer program can accept cost revisions at a later date.

Capital and operating costs for the HARDING were calculated as follows:

Information received from the Portland District of the Corps of Engineers * indicated that the book value of the HARDING on 30 June 1973 was $2,003,051.29 and that the estimated remaining life was 13 years. The annual costs for repairs and replacement were $525,036.00 in FY 1972 and $702,979 in FY 1973. Amortizing the book value over 13 years at 6 7/8% (the San Francisco District requested that this interest figure be used in economic calculations rather

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* Letter from Chief, Plant Branch, Portland District, January 14, 1974.

than the 5 1/2% figure specified in the Scope of Services), the annual cost was found to be $237,970. Adding to this the average of 1972 and 1973 repair and replacement costs of $614,007, the total becomes $851,977. Escalating this to the third quarter of FY 1974 by a 5% increases, the annual cost becomes $894,576. This compares closely with a figure of $935,642 derived by escalating the "Plant Rental" figure of $742,043 (46.57% of $1,593,393) shown on the FY 1971 Consolidated Statement of Operations to 1974 prices. Operating costs were calculated by escalating the figures for payroll, fuel, insurance, and miscellaneous costs shown in the same document to 1974 prices. These figures for 1974 are:

• Payroll	$ 878,422
• Fuel	116,930
• Insurance	4,822
• Miscellaneous	73,333
Total	$1,073,507

The additional capital cost of the hopper dredge with direct pumpout was calculated by amortizing the $2,000,000 investment of pumpout modification over 20 yearsat 6 7/8% to arrive at a figure of $186,955. Even though the HARDING is estimated to have only a 13 year life remaining, this assumption was assumed to be reasonable for hypothetical purposes.

The actual operating time of a hopper dredge or any other piece of dredging machinery is a variable, depending on weather, breakdowns, availability of work, etc. For purposes of this study, it was assumed that all dredges would be used 5000 hours per year. If the quantity of dredging per year exceeds the amount that a given dredge could accomplish in a 5000 hour period,it was assumed that another piece of similar equipment would be available.

Spreading the capital and operating costs of the hopper dredge over 5000 hours, the following hourly costs were found:

Capital Cost: (Plant Rental)	$ 935,642 ÷ 5000	= $187.13
Operating Cost	1,073,507 ÷ 5000	= 214.70
	Total	$401.83 per hour

For the hopper dredge with pumpout capability, the figures became:

Capital Cost:	(\$ 935,642 + 186,955) ÷ 5000	= 224.19
Operating Cost:	1,073,507 ÷ 5000	= 214.70
	Total	\$438.89 per hour

4.2.3 Clamshell Dredges - This type of dredge consists essentially of a barge-mounted crane with a clamshell type bucket. The clamshell mechanically cuts into the bottom material, removes it, and drops it either onto land or into a scow for transport. For purposes of this study, 3 sizes of clamshell dredges were analyzed to cover a representative range: 9, 13 and 18 cubic yard bucket sizes.

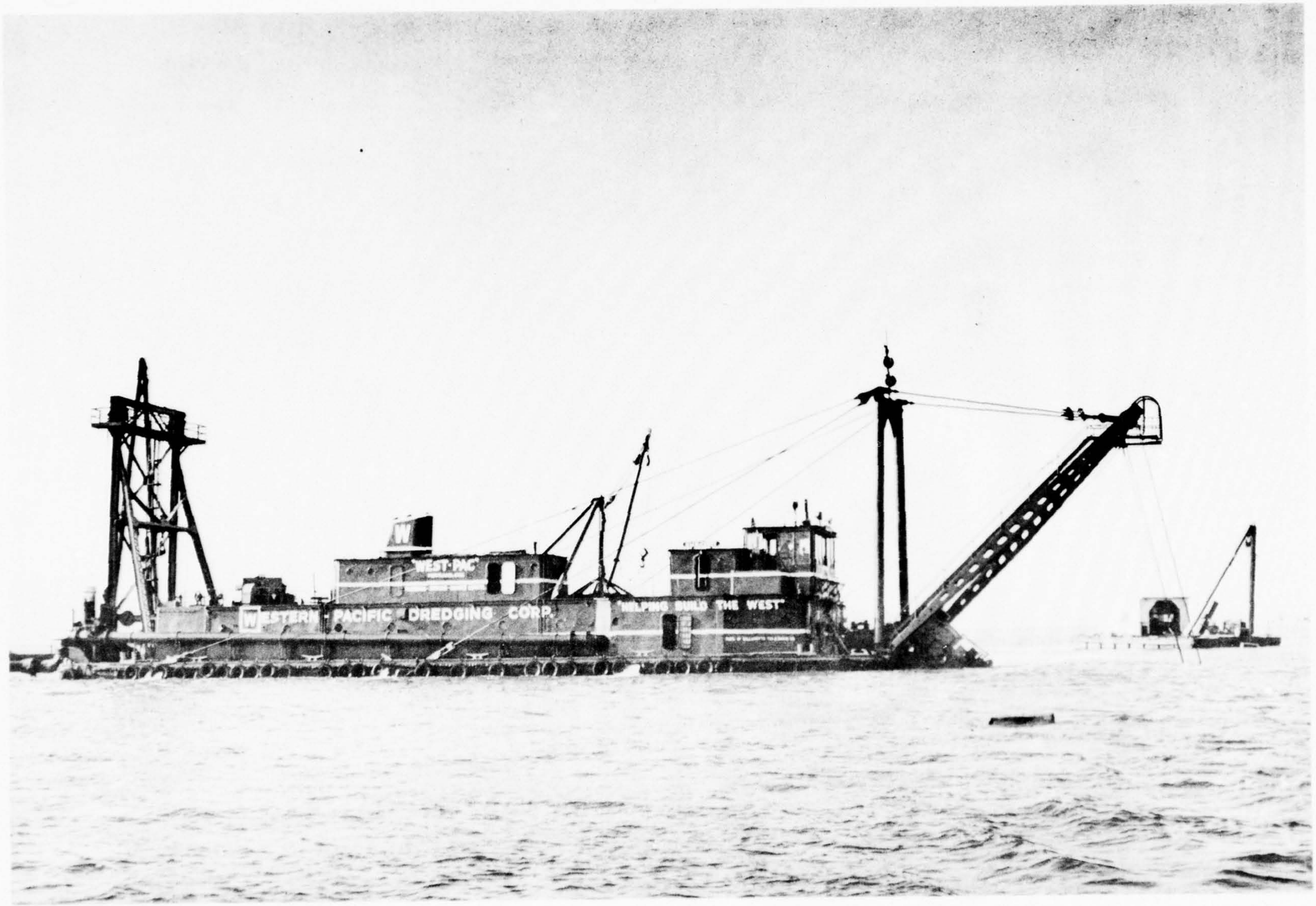
Clamshell dredges generally cause less disturbance and bulking to dredged materials than other dredging methods; materials can be transported in a more "compact" form.

Production rates of clamshell dredges were estimated for two conditions: First, rates for average equipment, under good conditions and second, for a comparison, rates of equipment which could conceivably become available, tailored to San Francisco Bay dredging conditions. These are tabulated below:

Maximum Production Per 3 Shift Day
(Cubic Yards Per Day)

Size	Average Machine	S.F. Bay Machine
9 cy	6,500	7,800
13 cy	9,400	11,200
18 cy	13,000	15,600

CLAMSHELL DREDGE - GREAT LAKES DREDGE AND DOCK CO.



HYDRAULIC DREDGE - WESTERN PACIFIC DREDGING CORP.

Initial costs and hourly rates used in the simulation model (Chapter VII) were as follows:

Size	Initial Cost	Hourly Rate
9 cy - Avg	$2,045,000	$170.15
9 cy - SF Bay	2,454,000	179.02
13 cy - Avg	2,873,000	194.72
13 cy - SF Bay	3,448,000	207.19
18 cy - Avg	3,773,000	220.12
18 cy - SF Bay	4,528,000	236.66

4.2.4 Hydraulic Suction Dredges - This type of dredge removes bottom sediments by sucking them up and pumping them through a pipeline. Hydraulic dredge sizes are indicated by the diameter of the discharge line. Although a great many sizes are available, four were selected for inclusion in this study because it was felt they would represent a good range for this type of dredge: 16-inch, 24-inch, 30-inch, and 36-inch.

Size alone is a poor but relative indicator of the productivity of a hydraulic dredge. The speed with which the dredge moves, its pumping capability, dredged material characteristics, and length of discharge line can cause significant variations in production. In this study, production rates for average equipment and also for equipment more tailored to San Francisco Bay conditions have been estimated to provide a representative range.

In removing material, a hydraulic dredge vacuums up material along with water to form a slurry mixture. This removal process yields a product quite different from the in-place material or that removed by a clamshell dredge because of an increase in water content. This may be an advantage or a disadvantage depending on disposal requirements.

The larger sizes of dredges, 36-inch and above, are scarce. One 36-inch dredge, the Hydropacific, is a good example of a very powerful specially - designed dredge. Electrically powered, it is now cutting through coral in the Hawaiian Islands at the high rate of approximately 60,000 cubic yards per day. Another noteworthy hydraulic dredge is the 42" Triton, working in South America. Dredging at 100 ft. depths in 8 ft. swells, this dredge is producing over 100,000 cubic yards per day.

Estimated local production rates for hydraulic dredges used in the simulation model are as follows:

Maximum Production Per 3-Shift Day
(Cubic Yards per Day)

Machine	Average Machine	S.F. Bay Machine
16-inch	10,000	12,500
24-inch	20,000	25,000
30-inch	30,000	37,000
36-inch	40,000	50,000

Average costs of hydraulic dredges used in the simulation model are as follows:

Machine	Initial	Hourly
16-inch Avg.	$1,111,000	$157.33
16-inch SF Bay	1,333,000	162.70
24-inch Avg.	3,000,000	276.44
24-inch SF Bay	3,600,000	289.45
30-inch Avg.	4,386,000	351.46
30-inch SF Bay	5,263,000	370.48
36-inch Avg.	4,886,000	383.94
36-inch SF Bay	5,863,000	405.13

4.2.5 Other Types of Dredges:

- Dipper Dredge - Used primarily for submerged rock excavation, this dredge is basically a power shovel on a barge. It works relatively slowly and is not believed to be competitive for San Francisco Bay work.

- Dragline Dredge - Also basically a piece of construction equipment, mounted on a barge. It has been found to be less productive than the clamshell dredge in San Francisco Bay.

- Bucket Line Dredge - This dredge digs using a conveyor belt fitted with many small buckets. Bucket line dredges are expensive to operate and require relatively calm water in which to work. Also, this type of dredge requires many mooring lines. This dredge was eliminated from the study because it would encounter adverse operating conditions in the Bay.

- Cutterhead Hydraulic Dredge - This type of dredge is very similar to the hydraulic suction type except that it is fitted with a rotating cutterhead at the intake or the suction pipe. It is believed that the cutterhead is not required to accomplish normal maintenance dredging in the Bay.

- Sidecasting Hopper Dredge - This variation of the hopper dredge is fitted with a long pipe protruding from the side of the dredge which discharges material as the dredge works. Given the characteristics of Bay sediments and the policies regarding dredging, this dredge is probably infeasible for Bay work.

4.3 TRANSPORTATION EQUIPMENT

4.3.1 General - Three basic modes for the transport of dredged material were considered in this study: the hopper dredge, tug and scow, and pipelines. Although any of these can constitute an entire transport system, many possible combinations exist; the feasible combinations are detailed in Chapter VII.

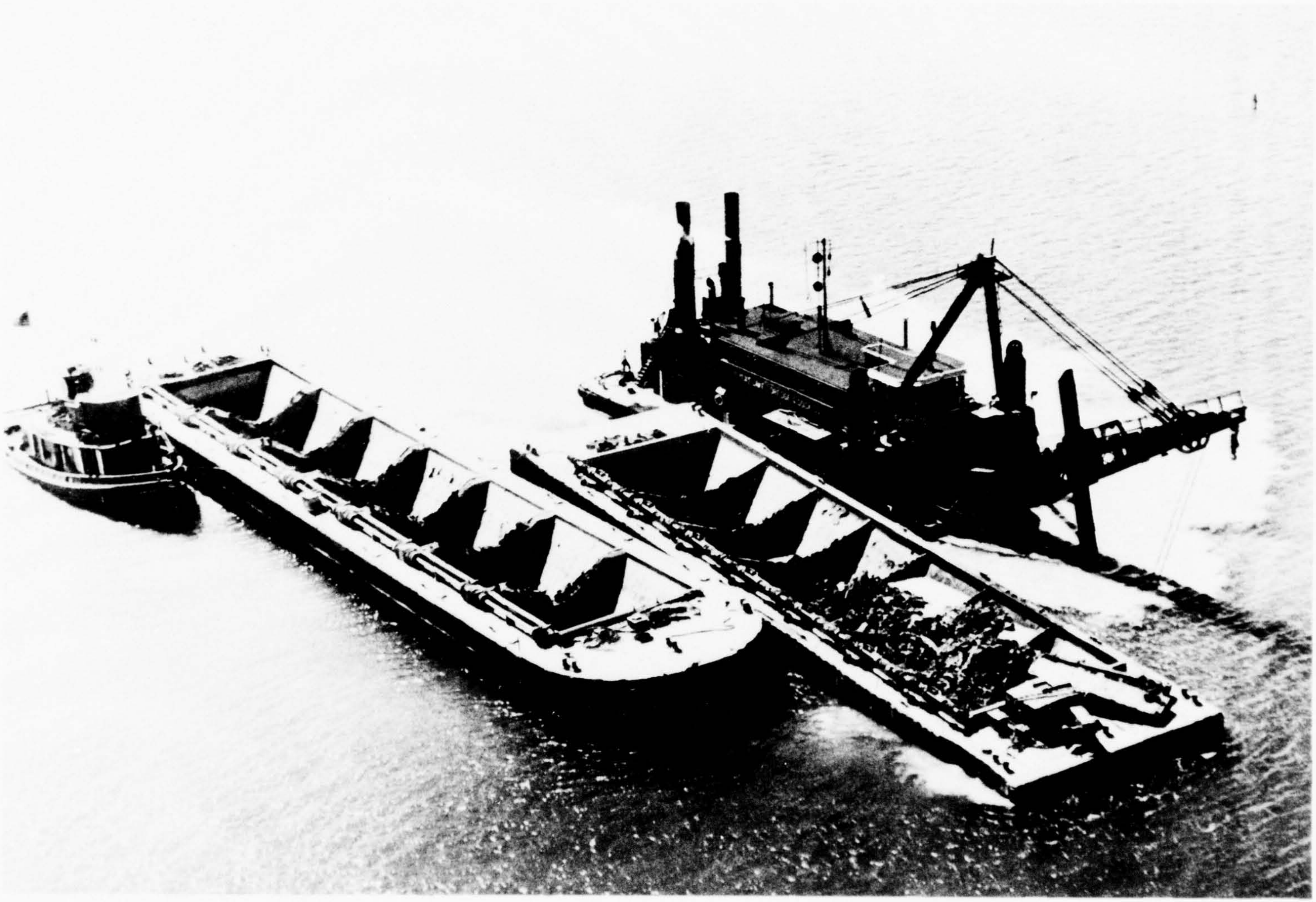
4.3.2 Hopper Dredge - After loading itself, the hopper dredge retracts its trailing arm dredging pipes and carries its load to its destination. As a transport element, a hopper dredge was assumed in this study to move at the rate of 5 mph in restricted channels and at 10 mph in open water. The latter figure is the average of loaded and unloaded speeds. The 5 mph maximum must be observed while working in the channels of Mare Island, Oakland, Richmond and Redwood City.

Assuming that the costs of the hopper dredge are relatively constant whether digging or transporting, the same hourly rate was used for both operations.

Although the hopper dredge is an efficient digging machine, it is an expensive transport mode because of its high operating cost, due primarily to its large crew (60 men +).

4.3.3 Tugs and Scows - Tugs and scows are evaluated in this study for transport of dredged material from either clamshell dredges or direct pumpout hopper dredges to disposal sites or transfer stations. Two types of scow were considered: bottom dumping and non-bottom dumping. Five sizes of tugs (1000, 2000, 3000, 4000, 5000 horsepower) and six sizes of scows (1000, 2000, 3000, 4000, 5000 and 6000 cubic yard) were studied to give a representative equipment spread.

Performance of tugs and scows is dependent on a number of variables, some of which can be anticipated and others which are random. It was assumed in preparing input to the model that highly efficient tugs and scows would be used. Because of the complexities involved, no attempt was made to



DIPPER DREDGE, TUG, and SCOWS

program effects of winds, waves and tides, which many have a considerable effect on tug/scow speeds and costs. Allowable combinations of tugs and scows were based on speed, distance and handling considerations, and, for maximum efficiency, only one scow was assumed to be handled by by a tug. Tug-scow speeds were averages developed using dynamic resistance factors based on form and shape characteristics for efficient tug-scow combinations.

Available scow capacity at least equal to the dredging rate must be maintained by proper cycling of scows with tugs. The following equations define the relationships involved:

1. Scow Loading Time $= \frac{\text{Scow capacity}}{\text{Dredging Rate}}$: $SLT = \frac{SC}{DR}$

2. Scow Cycle Time $= \frac{\text{Haul Distance (Round Trip)}}{\text{Tug Speed}} + 0.5$ hr:

   $SCT = \frac{D}{TS} + 0.5$

   The 0.5 hr. factor is the time required to hitch and unhitch a scow from a tug.

3. $SCT \leq n\,(SLT)$ where n is an integer. This must be true to keep the disposal rate at least equal to the dredging rate. Also, if SCT is less than n (SLT), there will be idle tugs and scows.

   The number of scows, $S = n + 1$

   The maximum number of tugs, $T = n$

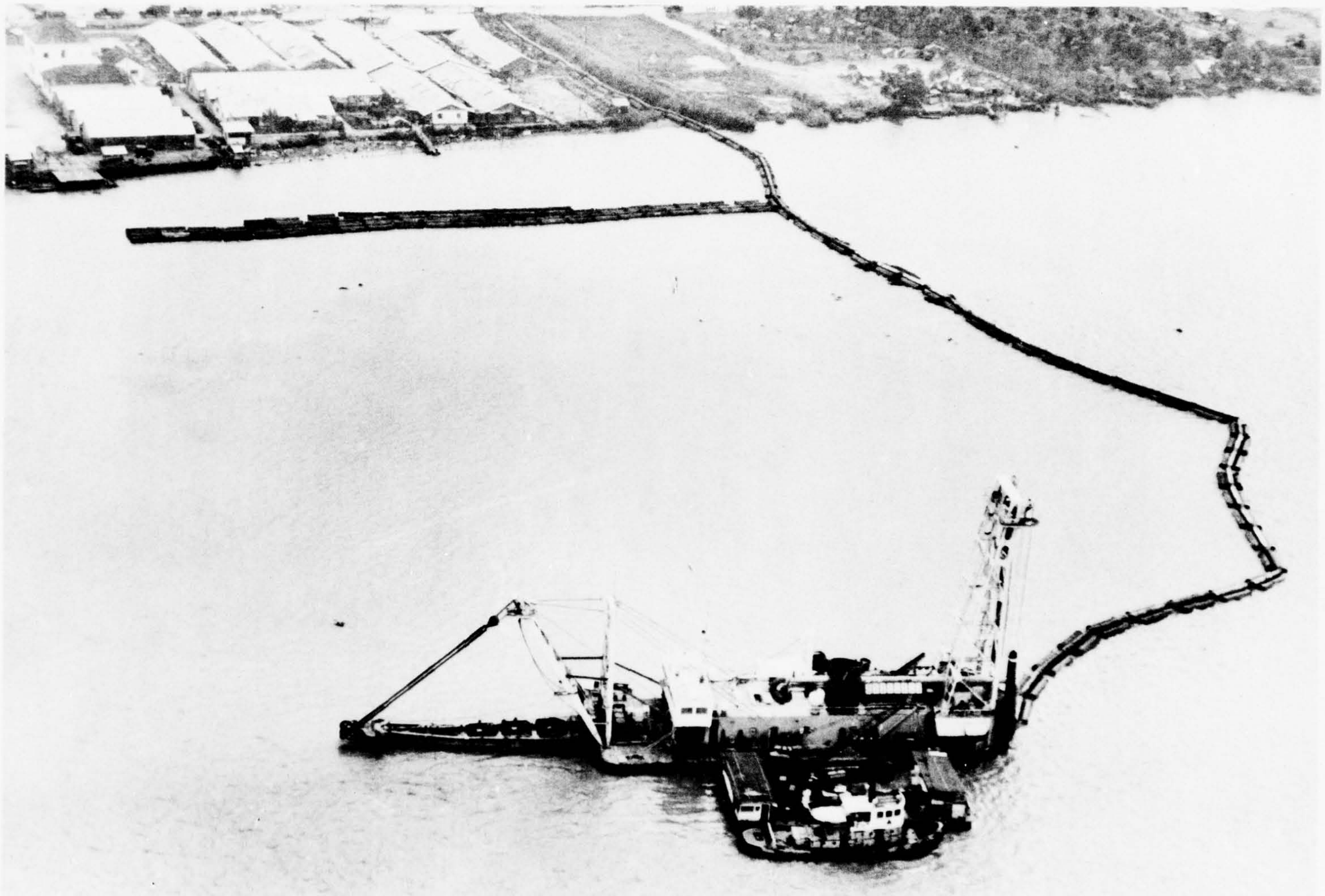
In the event more than one dredge is working on a project, T may be less than n if enough idle time exists for the tug to handle scows from each dredge.

A subroutine is included in the simulation model to select the most efficient tug-scow combinations for any given project operation.

Hourly costs for tugs and scows were developed in a manner similar to those for dredges except that tugs, because of their versatility, were assumed to work 5500 hours per year in lieu of the 5000 hours assumed for other equipment. Costs used in the dredge simulation model included the following:

Equipment	COST Initial	COST Hourly
1000 hp Tug	$ 725,000	$ 85.17
2000	950,000	99.92
3000	1,300,000	117.77
4000	2,520,000	155.76
5000	3,640,000	191.35
1000 c.y. scow (bottom dump)	452,000	29.35
2000	680,000	35.90
3000	910,000	42.26
4000	1,030,000	45.80
5000	1,305,000	53.32
6000	1,480,000	58.26
1000 c.y. scow (not bottom dump)	346,000	8.51
2000	521,000	12.50
3000	697,000	16.52
4000	790,000	18.74
5000	1,000,000	23.50
6000	1,134,000	26.60

4.3.4 Pipelines - Transport of dredged material by pipeline is commonplace in the dredging industry. Hydraulic dredges pump as far as two or three miles with dredge pumps alone and farther with remote booster units.



HYDRAULIC DREDGE AND FLOATING PIPELINE - MORRISON-KNUDSEN CO.,INC.

Use of pipelines for long distance transport of solids in slurry form has received increasing attention in recent years in the mining, construction, and other industries. Ref. 10 cites examples of transport of coal slurry 108 miles, gilsonite 72 miles, and many others. Ref.52 reports information on the transport of coal slurry 273 miles through an 18-inch pipe with 4 booster stations, and transportation of waste tailings 44 miles with one pump station. The Philadelphia District of the Corps of Engineers (Ref. 55) detailed a proposed system of transporting dredging material 25 to 50 miles using pumping stations spaced at 12,500-foot intervals.

In this study two basic pipeline types were considered: temporary and fixed. A temporary pipeline is defined as one used only for the duration of a dredging project and then removed, whereas a fixed pipeline is a permanent installation, in place for at least twenty years. In this study, temporary pipelines lead to disposal sites or to the water side terminus of a fixed pipeline system. Generally, it was assumed that temporary pipelines leading from hydraulic dredges would be limited to three miles in length. These lines could either be floating lines or underwater lines. For temporary lines leading from a booster station, two sizes were used: 22-inch and 28-inch, and, since they were usually longer than the type described above, they were assumed to be laid underwater to reduce the hazard to navigation. Fixed pipelines were planned from a terminus in San Pablo Bay to the land disposal sites at Petaluma River and Sherman Island, and as an alternative, from the San Pablo Bay transfer point to the 100-fathom line outside the Golden Gate. Plate IV-1 delineates the tentative pipeline layouts. The fixed pipelines were standardized at 28-inch diameter and were all assumed to be underwater lines. Pumping arrangements for the various pipeline layouts are described in Section 4.4.

Pipeline lengths for lines to the land disposal sites were calculated from the intake of the pipeline to the end of an assumed distribution system at the disposal site. Pipelines to water disposal sites were assumed to terminate in a diffuser on the bay or ocean floor at the site. It is recog-

nized that little precedent exists for such an installation; however, diffusers have been used successfully for the underwater discharge of sewage and other pipeline transported materials. The Bechtel Report (Ref. 11) for example, discusses disposal of sewage sludge in suspension by the use of underwater diffusers. Several technical problems are associated with diffusers. For example, a slurry of the consistency desired for maximum efficiency in pumping might be too thick to diffuse easily. Also, provision would have to be made for maintenance of the nozzles to prevent plugging. However, it is felt that the technical problems of such an installation are not insurmountable, and the idea of discharge in a deep underwater confined area or in an area of strong dispersing currents has enough merit to warrant its inclusion as a potential alternative.

Costs of pipeline materials were obtained from local dealers. Installation costs were determined from discussion with local contractors and by drawing on the experience of IECO's parent company, Morrison-Knudsen Company, Inc. The estimated costs for the sizes of pipes used in the study are:

Size	16-inch	22-inch	27-inch	28-inch	30-inch	36-inch
Pipe Cost	$22.15	$26.43	$30.00	$31.60	$35.00	$62.40
Installation Cost	3.51	4.82	5.90	6.12	6.51	7.81
Total	$25.66	$31.25	$35.90	$37.72	$41.51	$70.21

For the fixed pipelines, the installation cost was incurred once; for the temporary pipelines, it was assumed that the removal cost would be one-half of the installation cost.

Although transport of dredged material through long pipelines is undoubtedly feasible, it must be borne in mind that the layouts described in this study are conceptual only, and that many technical, economic and environmental factors will have to be considered before such a system can be built.

4.3.5 Other Transportation Equipment - Consideration of other transport modes for dredged materials included pipelines on land, railroad cars, and trucks. A logical land pipeline route for example, would extend from near the center of gravity of Bay dredging projects (in the vicinity of Richmond) along the northern Contra Costa shoreline to a disposal site in the Delta. This plan would require acquisition of right-of-way through highly urbanized areas and construction involving utility relocations, road and water crossing, etc. Since this type of construction would be considerably more expensive than that of a pipeline in the Bay and probably would involve at least as many administrative and environmental constraints, this alternative was not pursued.

Several factors militate against the use of rail or truck transport of dredged materials. Since it would be uneconomical to transport a slurry of 85% or more water by railroad car or truck, transport by this mode would probably be limited to material excavated by mechanical, rather than hydraulic means, unless a facility were constructed for dewatering the material. Also, railroad cars or trucks would have to be water tight to prevent discharge of the material. Coordinating the movement of the large number of trains or trucks required with railroad schedules and through city traffic would be extremely difficult. Rehandling facilities would be required to load the material from the scow or other conveyance to the railroad car or truck and also at the other end to unload it into the transport mode taking it to the disposal site.

Relative costs for these transport methods are indicated in a recent (1972) report on disposal of wastewater and residual solids (Ref. 53). This study reported the cost of truck transport of wastewater sludge for hauls up to 50 miles ranged from $0.80 to #2.00 per ton-mile (dry solids); railroad transport (50-200 miles) ranged from $0.60 to $6.00 per ton-mile (dry solids); barge transport (20 to 200 miles) ranged from about $0.15 to $1.50 per ton-mile (dry solids); and pipeline transport (any distance) ranged from $0.11 to $1.02 per ton-mile (dry solids).

For the foregoing reasons, truck and railroad transport were not considered further.

4.4 TRANSFER EQUIPMENT

4.4.1 General - Transfer equipment is proposed for use in changing transport modes; the primary purpose of this equipment is to effect transport economy, efficiency and convenience.

Only certain elements of the proposed equipment have been used in dredging practice; others are conceptual elements only and would require further design and testing before use.

Three basic types of transfer stations were studied. The first is a mobile unit which could be moved as needed. This unit could be barge mounted and would supply four services: pumping; direct scow pumpout (slurry reconstituting); dredged material conditioning to optimum consistency; and a reservoir capacity. This unit would also supply services required at the other two types of stations. The second type of transfer station is a fixed installation which would be located in San Pablo Bay near the center of gravity of the dredging projects included in this study. Third, fixed stations located at each land disposal site were considered.

4.4.2 Mobile Transfer Units - This type of unit could be stationed temporarily in the Bay for a particular dredging project or permanently in order to provide services at the proposed San Pablo Bay transfer station or at a land disposal site station. A number of these units have been conceptualized, each providing a slightly different range of services. The services include (1) pumping materials received at the station through various types of pipelines; (2) removal of materials from non-bottom dumping scows brought alongside; (3) conditioning of materials received to allow pumping at a maximum efficiency, and; (4) a reservoir capability which would allow direct receipt of materials from either a hopper dredge with pumpout capability or a clamshell dredge. Some of the units have more pumping capability than others while some use diesel power and others electric. The intent of including a range of these units was to determine the most efficient unit required for each possible dredge/transport system. A sketch of a typical mobile unit is included as Plate IV - 2.

Cost estimates for the mobile transfer units were developed based on information obtained from local fabricators contractors, and pump manufacturers. Table IV-2 displays the range of units studied, their capabilities and their unit costs. In Chapter VII, the locations of the units are described in the various dredge/transport systems.

4.4.3 <u>Fixed Transfer Station - San Pablo Bay</u> - Plans were formulated for a major transfer facility at a point in San Pablo Bay, adjacent to the navigation channel, about six miles offshore from the Petaluma disposal site. This point was chosen as being close to the center of gravity of dredging in the Bay and also accessible by hopper dredge or scow. Two alternative designs were studied for this location: the first consists of a sheet pile enclosed dump basin open at both ends, about 600 feet long and 150 feet wide, with its bottom dredged about 15 feet deeper than the adjacent bay. This installation is shown on Plate IV-3; the second consists of a simple pipeline terminus surrounded by breasting and mooring dolphins. Power to operate either facility would come from a mobile transfer unit moored at this site.

Planned operation of the first design alternative would allow a hopper dredge or bottom dump scow to enter the enclosure, dump its load, and continue its circuit back to the dredging area. The dumped material would be removed by the use of a small hydraulic dredge or an intake system installed in the bottom of the basin. This latter system would consist of intakes leading to a discharge pipe and jets which would be used for reconstituting the dumped material into a slurry for pipeline transport. The material would be transported through a fixed pipeline to one of the land disposal sites in the north bay/Delta area or to the 100-fathom line.

The concept of bottom dumping and rehandling is long established. This technique always involves the problem of increased turbidity. It is assumed that with the system proposed, the dumped material would be localized in the sump and the spread of turbidity would be minimized. This could be the subject of further analysis and, if it is found to be a serious problem, consideration could be given to the used of silt barriers (polyvinylchloride screens) such as referred to in Ref. 51.

It is estimated that the capital cost of the transfer station described would be $1,250,000, of which about $1,175,000 is for piling and other structural work and $75,000 is for excavation. The operating cost is estimated to be $10,000 per year.

The second design alternative for a permanent transfer facility in San Pablo Bay would consist of only a terminus for the fixed pipeline adjacent to a line of cluster piles or dolphins for mooring a hopper dredge or scow. In this case, the dredge or scow would tie up to the dolphins and would be pumped out directly into the fixed pipeline leading to the land disposal sites or to the 100-fathom line.

It is estimated that the capital cost of this installation would be $150,000 and the operating costs $2,000 per year.

4.4.4 Transfer Station at Land Disposal Site - Another potential transfer point consists of a turning basin/reservoir constructed at a land disposal site. This type of facility would allow operations similar to those at the remote San Pablo Bay facilities previously described to occur at a land site.

For each land disposal site, different considerations are involved. In the case of the Petaluma River site, this would involve deepening the existing channel to the site (six miles ±) in addition to dredging the turning basin/reservoir. At the Montezuma Slough site, the existing slough west of Collinsville could be deepened, and at the Sherman Island site, the basin could be excavated adjacent to the channel. Two of the basins are shown; on Plate VI - 10 (Petaluma), and VI - 12 (Sherman Island).

The capital cost of the rehandling basin at the Petaluma site is estimated to be $6,000,000, of which $1,600,000 would be for excavating the basin and $4,400,000 for dredging a 30-foot deep channel to the site. The operating and maintenance cost for this facility is estimated to be $40,000 per year. The capital cost of the rehandling basin at the Sherman Island site is estimated to be $1,400,000, the majority of which would be for excavation, and the operation and maintenance cost to be $10,000 per year.

TABLE IV - 1

DREDGE PRODUCTION RATES (Cubic Yards Per Day)

Site	CLAMS 9 cy	CLAMS 13 cy	CLAMS 18 cy	HYDRAULICS 16"	HYDRAULICS 24"	HYDRAULICS 30"	HYDRAULICS 36"	HOPPERS Bottom Dump	HOPPERS Direct Pumpout
Suisun	5000 6600	6100 9500	7500 12800	5700 8600	7400 11800	9900 16000	11900 19000	33,600	39,700
Mare Island	4900 5900	7100 10600	9800 11700	7500 9400	10900 17400	14600 23500	17400 28000	34,700	41,700
Napa River	5000 6600	6100 9500	7500 12800	5300 -	- -	- -	- -	-	-
Petaluma	4400 7000	5400 9000	6600 11300	4700 -	- -	- -	- -	-	-
Pinole Shoal	5500 6600	8000 9500	10000 13300	7600 10600	9900 15700	13200 21300	15800 25400	33,600	39,700
Rich. Long Wharf	5900 7800	7200 11200	8900 15100	6700 10100	8700 13900	11700 18800	14000 22400	26,400	31,200
San Rafael	6500 7800	8400 11200	10300 15600	7400 -	- -	- -	- -	-	-
W. Rich. Channel	5300 7000	6500 10100	8000 13600	6000 9100	7800 12500	10500 16900	12600 20200	33,600	39,700
Rich. Pt. Molate	5900 7800	7200 11200	8900 15100	6700 10100	8700 13900	11700 18800	14000 22400	23,500	27,500
Oakland	4400 5900	5400 10600	6600 11300	5000 7600	6500 10400	8800 14100	10500 17000	24,500	28,600
San Francisco	5300 7000	6500 10100	8000 13600	5700 8600	7400 11800	9900 16000	11900 19000	26,900	32,200
Redwood City	5300 7000	6500 10100	8000 13600	6000 9100	7800 12500	10500 16900	12600 20200	31,200	37,600

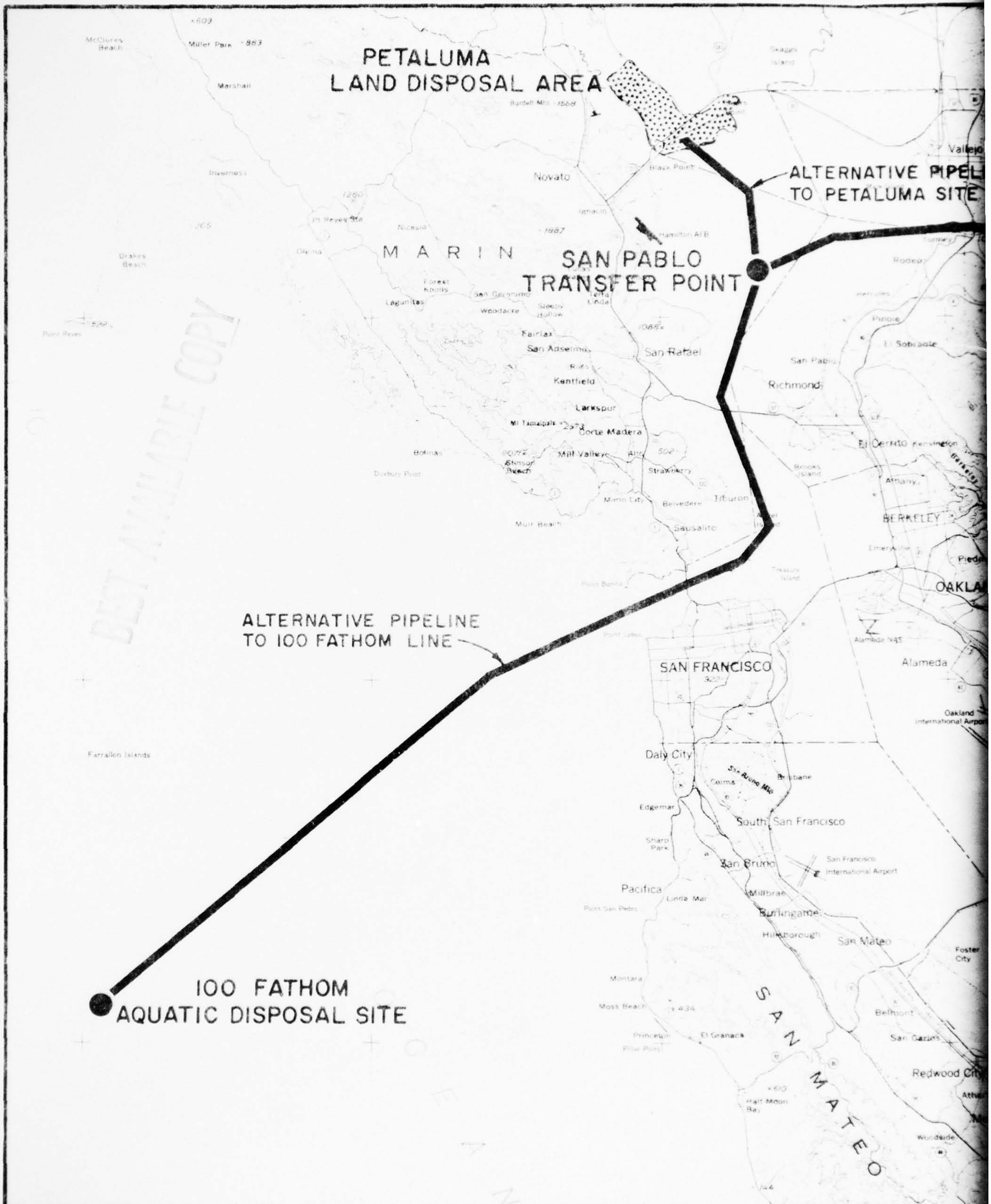
NOTES:

1. Production rates are cubic yards of shoal material per 24 hour day.
2. For clams and hydraulics, upper figure is minimum efficient rate, lower figure maximum rate.
3. For bottom dump hopper dredges, daily production rate is based on a cycle which includes one hour of travel in addition to loading, turning, and dumping.
4. For direct pumpout hopper dredges, cycle includes loading and pumpout only.
5. Hopper dredge production per cycle based on averages from Corps records at each dredging site.

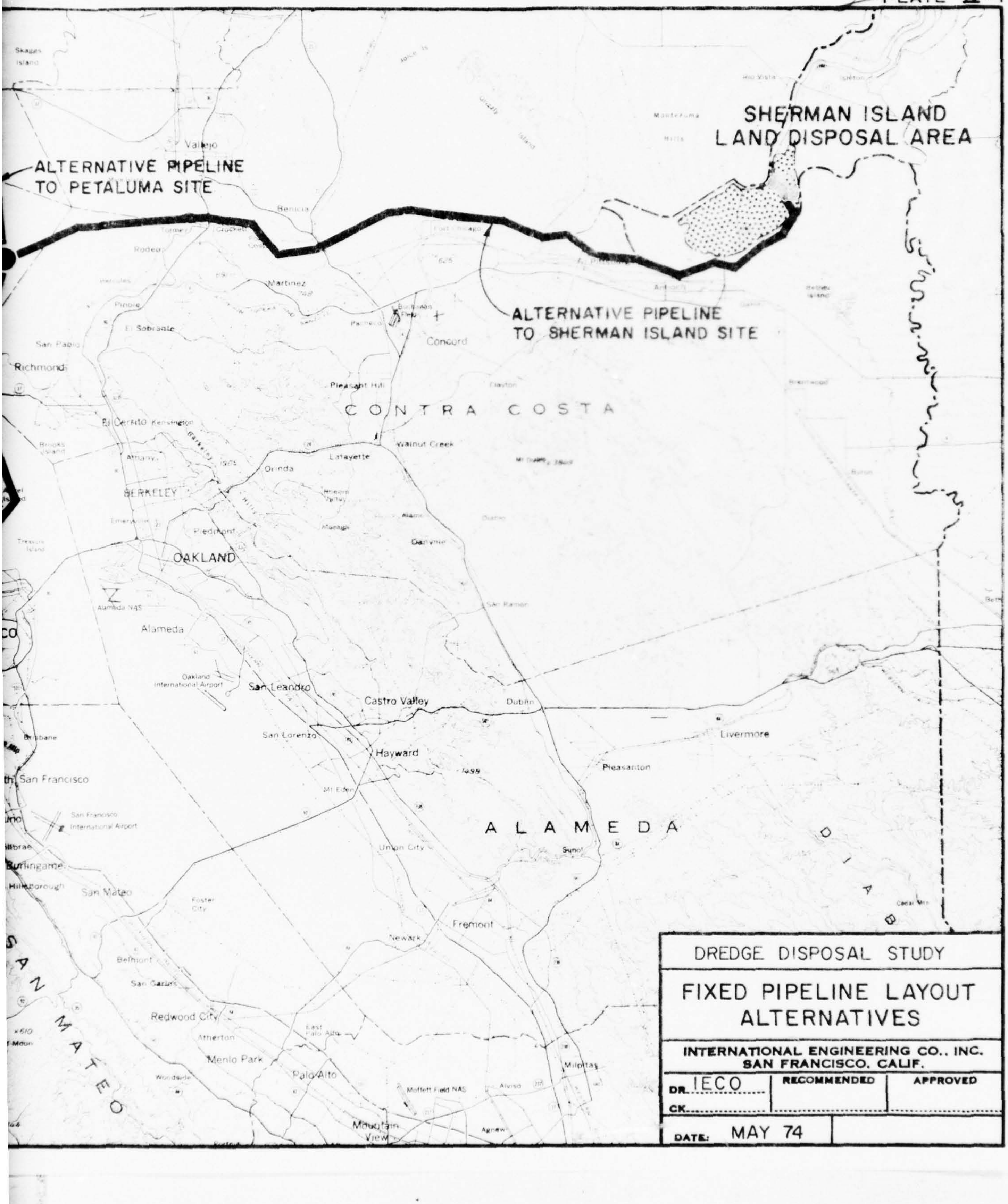
TABLE IV - 2

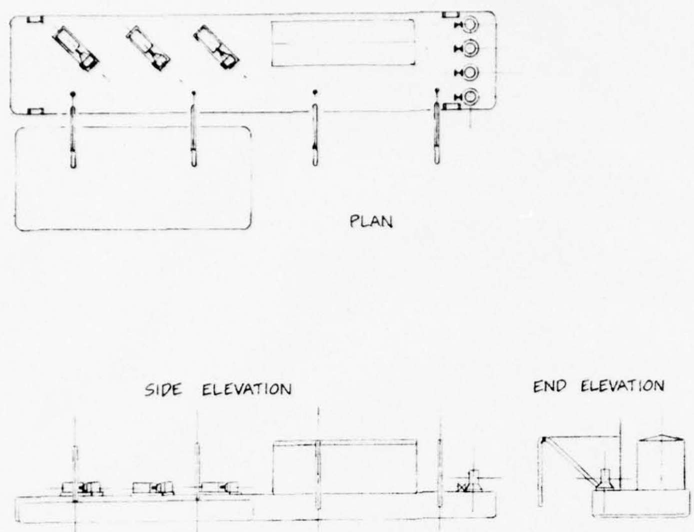
MOBILE TRANSFER UNITS

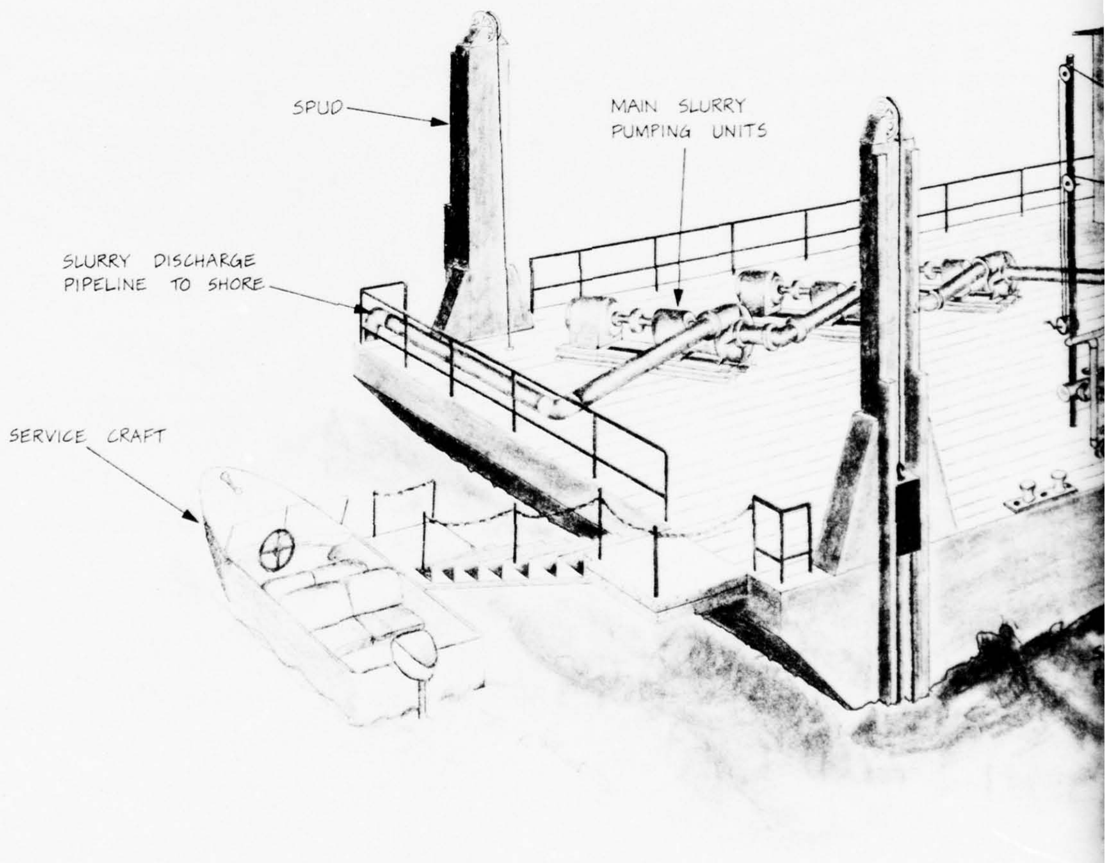
Unit	TU-1	TU-2	TU-3	TU-4	TU-5	TU-6	TU-7	TU-8	TU-9	TU-10
Capacity - cy/Day	36,700	36,700	36,700	36,700	20,000	20,000	20,000	20,000	36,700	36,700
Power	Electric	Electric	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Electric	Electric
Slurry Constituting	Yes	Yes	No	No	No	Yes	No	Yes	Yes	Yes
Reservoir	No	2000 cy	2000 cy	2000 cy	No	1000 cy	No	1000 cy	No	2000 cy
First Cost $\$ \times 10^6$	3,993	4,514	5,170	8,434	3,210	3,918	4,550	5,522	4,563	5,084
Cost \$ per Hour	47.34	53.52	80.55	131.40	50.01	61.04	70.89	86.03	54.10	60.28
Operating Cost \$ 4/cy-mi	0.00474	0.00478	0.00739	0.00491	0.00949	0.01021	0.00543	0.00576	0.00419	0.00422

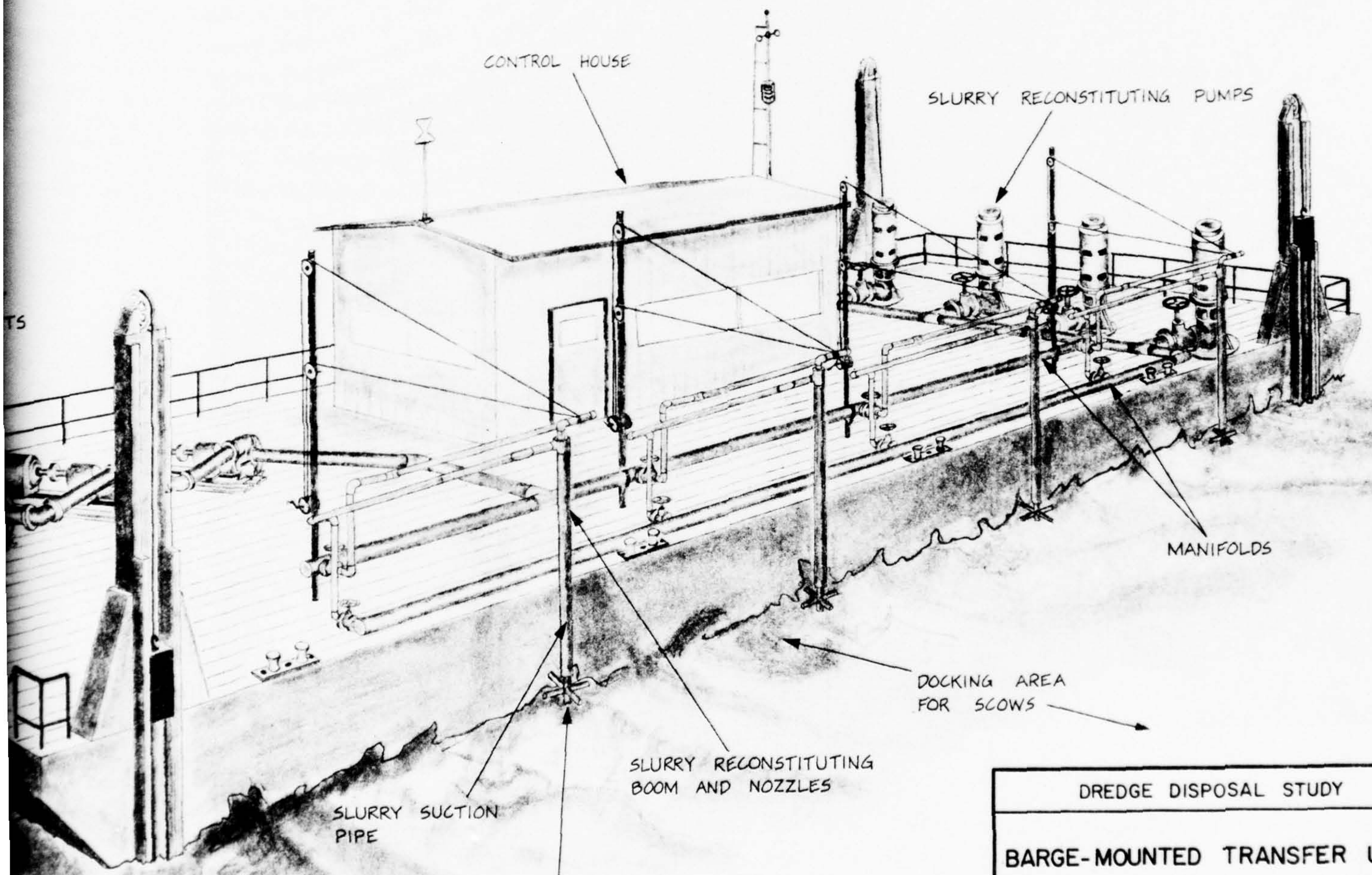


PETALUMA
LAND DISPOSAL AREA
ALTERNATIVE PIPEL
TO PETALUMA SITE
SAN PABLO
TRANSFER POINT
MARIN
ALTERNATIVE PIPELINE
TO 100 FATHOM LINE
100 FATHOM
AQUATIC DISPOSAL SITE
SAN MATEO
Marshall
Novato
Vallejo
Fairfax
San Anselmo
Kentfield
Larkspur
Corte Madera
Mill Valley
San Rafael
Richmond
San Pablo
El Sobrante
El Cerrito
Bolinas
Muir Beach
Sausalito
Belvedere
Tiburon
BERKELEY
SAN FRANCISCO
Alameda
Farallon Islands
Daly City
Edgemar
South San Francisco
San Bruno
Pacifica
Millbrae
Burlingame
Hillsborough
San Mateo
Moss Beach
Montara
Redwood City


SHERMAN ISLAND
LAND DISPOSAL AREA
ALTERNATIVE PIPELINE
TO PETALUMA SITE
ALTERNATIVE PIPELINE
TO SHERMAN ISLAND SITE
CONTRA COSTA
ALAMEDA
SAN MATEO
Vallejo
Benicia
Crockett
Rodeo
Martinez
Pinole
El Sobrante
San Pablo
Richmond
Concord
Pleasant Hill
Clayton
El Cerrito
Kensington
Albany
Orinda
Lafayette
Walnut Creek
BERKELEY
Piedmont
OAKLAND
Danville
Alameda
San Ramon
Oakland International Airport
San Leandro
Castro Valley
Dublin
San Lorenzo
Hayward
Livermore
Pleasanton
South San Francisco
San Francisco International Airport
Brisbane
Union City
Sunol
Burlingame
Hillsborough
San Mateo
Foster City
Newark
Fremont
Belmont
San Carlos
Redwood City
Atherton
Menlo Park
Palo Alto
Milpitas
Moffett Field NAS
Alviso
Mountain View
Agnew
DREDGE DISPOSAL STUDY
FIXED PIPELINE LAYOUT
ALTERNATIVES
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
RECOMMENDED
APPROVED
CK.
DATE: MAY 74


PLAN
SIDE ELEVATION
END ELEVATION


SPUD
MAIN SLURRY PUMPING UNITS
SLURRY DISCHARGE PIPELINE TO SHORE
SERVICE CRAFT

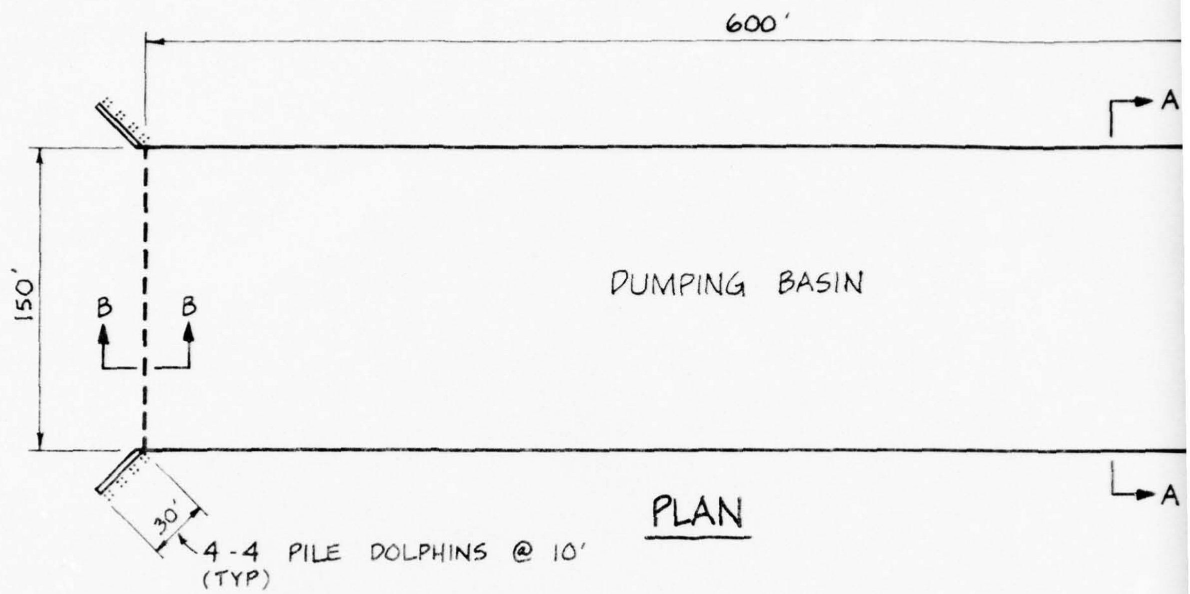


DREDGE DISPOSAL STUDY

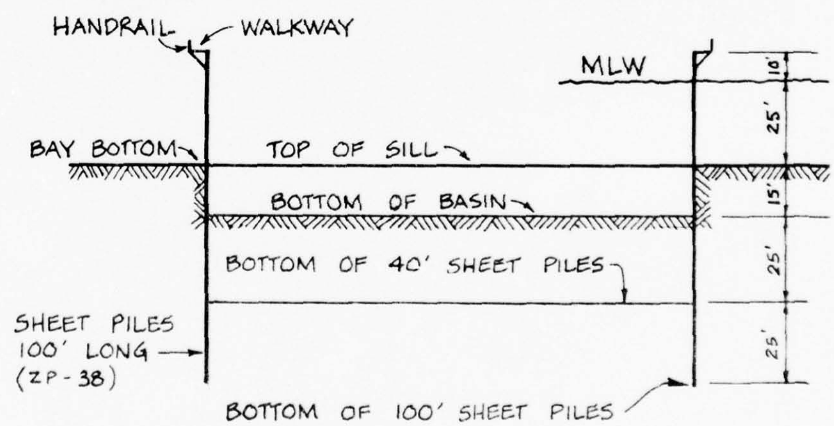
BARGE-MOUNTED TRANSFER UNIT

INTERNATIONAL ENGINEERING COMPANY, INC.

DESIGNED IECO DRAWN	CHKD INSP	SUBMITTED RECOMMENDED APPROVED
SAN FRANCISCO, CAL. DATE MAY 74		

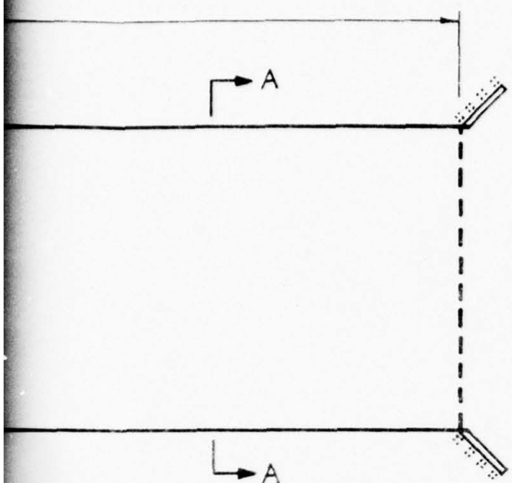


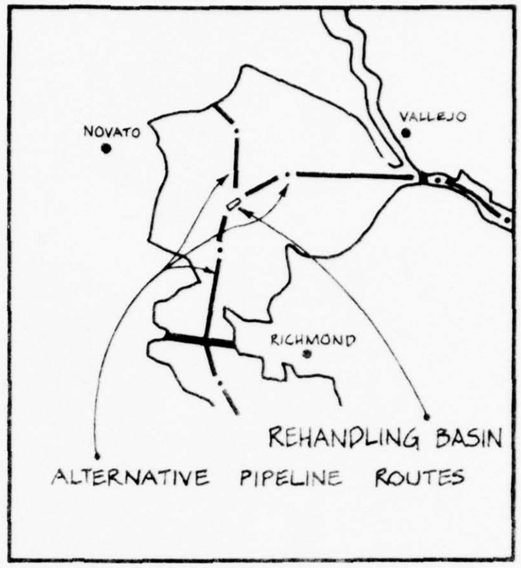
PLAN



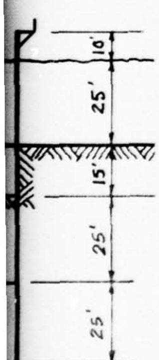
SECTION A-A

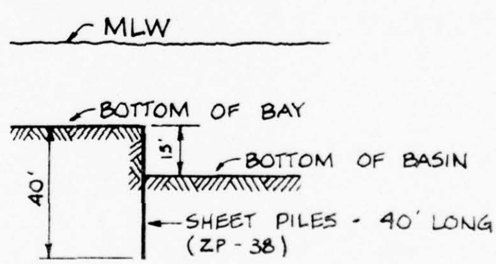
2





VICINITY MAP





SECTION B - B

DREDGE DISPOSAL STUDY		
REHANDLING BASIN SAN PABLO BAY		
INTERNATIONAL ENGINEERING CO., INC. SAN FRANCISCO, CALIF.		
DR. IECO CK.	RECOMMENDED	APPROVED
DATE: MAY 74		

CHAPTER V

AQUATIC DISPOSAL SITES

5.1 LOCATION

Five aquatic disposal sites in the San Francisco Bay and two outside the Golden Gate were specified by the Scope of Services. These are:

- Carquinez Strait

A rectangular area 1000' x 2000' with the long axis bearing 80^{O} T and the center of which is Latitude 38^{O} 03'47" N, Longitude 122^{O}15'55"W.

- San Pablo Bay

A rectangular area 1500' x 3000' with the long axis bearing 50^{O} T and the center of which is Latitude 38^{O}00'28" N,Longitude 122^{O}24'55"W.

- Alcatraz Island

A circular area 2000' in diameter the center of which is Latitude 37^{O}49'17" N, Longitude 122^{O}25'23"W.

- Hunters Point

A circular area 2000' in diameter the center of which is Latitude 37^{O}44'10" N, Longitude 122^{O}20'40"W.

- San Francisco Bay South

A rectangular area 1500' x 3000' with the long axis bearing 300^{O}T and the center of which is Latitude 37^{O}34'30" N, Longitude 122^{O}13'15"W.

• San Francisco Bar

About 2 miles square, 5000 x 1000 yards, 2500 yards south and parallel to the channel. Latitude 37^{0} 45'06" N, Longitude 122^{0} 35'45"W.

• Farallon Islands - 100 Fathom

29.6 nautical miles from the Golden Gate, 1000 yards radius, Latitude 37^{0} 31'45" N, Longitude 122^{0} 59'00" W.

Theses sites are delineated in Plate V-1.

5.2 CONSTRAINTS

Present California Regional Water Quality Control Board (RWQCB) policy is to allow disposal of dredged material only at certain sites depending on the degree and type of pollution in the sediments. These criteria are: sediments polluted with organic material may be disposed at the Alcatraz site, and sediments polluted with heavy metals may be dumped at the 100-fathom line. The background of this policy decision is this:

CRWQCB Resolution 72-15 states, in part:

"a. If none of the allowable concentration limits of the seven parameters except Zinc specified in EPA criteria are exceeded, the sediment will be classed as "not polluted" and will be allowed for dumping at one of five spoil disposal sites in the Bay which are proposed by the U.S. Army Corps of Engineers. The Regional Board Executive Officer will specify the appropriate disposal site on a case-by-case basis.

b. If any allowable concentration limits of the parameters except Zinc specified in EPA criteria are exceeded, the sediment will be allowed for dumping at a land disposal site approved by the Regional Board except that spoils "polluted" with heavy metals or organic matter may be allowed for aquatic disposal at sites specified by the

Regional Board on a case-by-case basis after weighing both the significance of the degree of pollution and the community values of the project, and if it can be demonstrated by the proponent to the satisfaction of the Regional Board that:

(1) Land disposal is not feasible, and

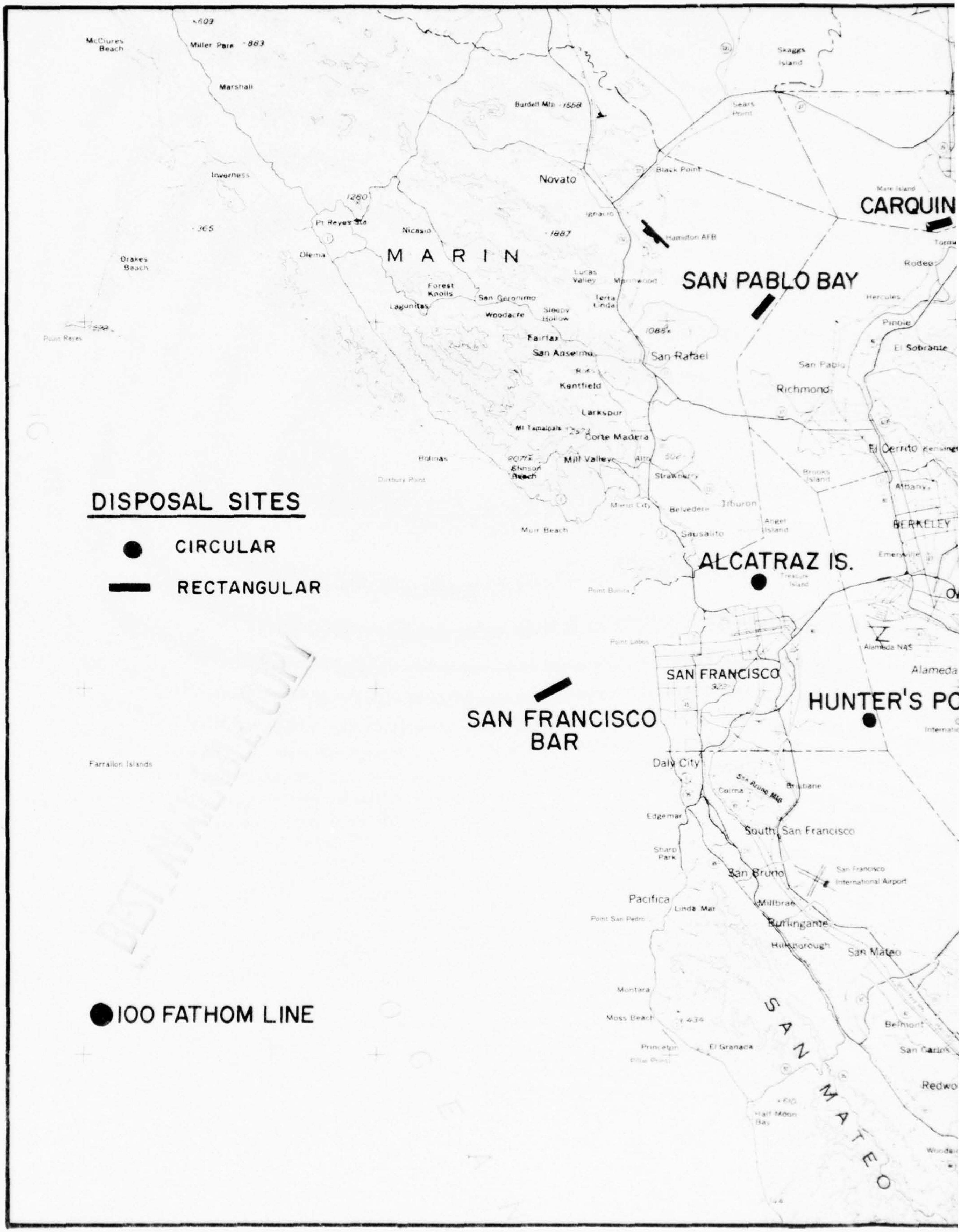
(2) The project is essential and must go forward, otherwise severe economic or social damage will result,and

(3) Additional funds are not available to permit the project to proceed in compliance with the Board's Interim Policy of April 25, 1972. It is not intended that an exception be granted on this basis more than once."

The resolution does not identify aquatic sites specifically which can be used for disposal of sediments polluted with organic matter or with heavy metals. However, RWQCB Resolution 72-4 states that sediments classified as "polluted with organic matter" will be allowed for dumping at the Alcatraz site. A memorandum from the San Francisco Regional Water Quality Control Board dated March 20, 1972, subject: Amendment of Policy with Respect To Regulation of Dredged Spoil Disposal in the San Francisco Bay Region, states that the Alcatraz site would provide rapid dispersion of disposed spoil and prevent accumulation of excessive organic matter. The memorandum also states that the Pacific Ocean at the 100-fathom line is at the edge of the continental shelf and at this location the settled solids will rapidly disperse.

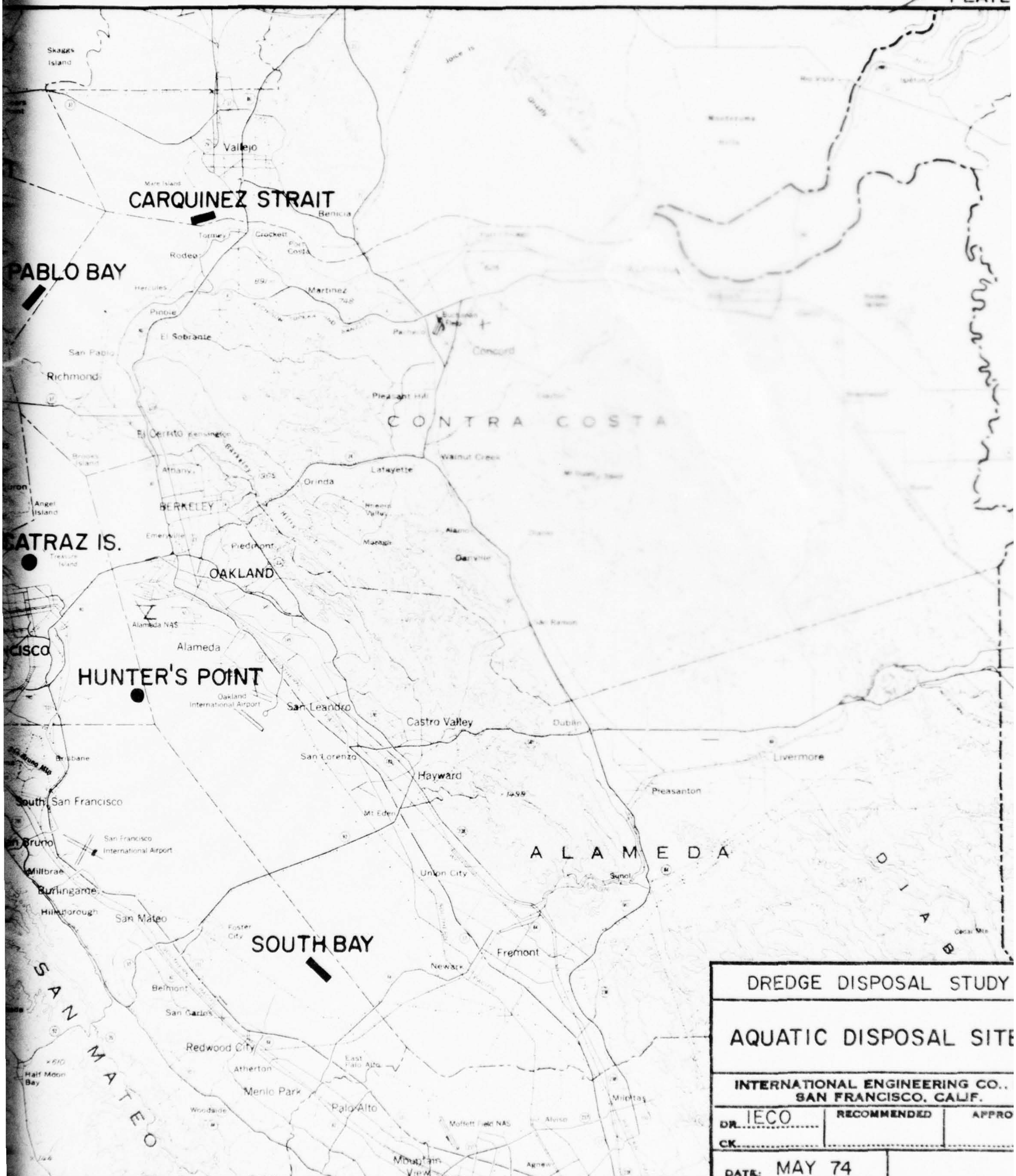
Another criterion for disposal of dredged material at aquatic disposal sites is the requirement that it must be disposed of to seaward. This is formalized in the San Francisco District's Public Notice No. 72-61 of 15 May, 1972, which states in part that "At no time would it be proposed that spoil would be transported away from the Golden Gate and deposited where more material could remain in the Bay."

As will be noted in Chapter VII, costs were determined for transport of dredged material from all dredging sites to: the closest aquatic disposal sites; the closest aquatic disposal sites conforming to the seaward disposal criterion; the 100-fathom line; and the aquatic and land disposal sites conforming to the RWQCB criteria. Costs were also determined for transport to land disposal sites. The computer program is flexible enough to accept changes in disposal sites if regulations are modified in the future.



DISPOSAL SITES
CIRCULAR
RECTANGULAR
100 FATHOM LINE
CARQUIN
SAN PABLO BAY
ALCATRAZ IS.
SAN FRANCISCO BAR
HUNTER'S PO
MARIN
SAN MATEO
SAN FRANCISCO
McClures Beach
Miller Park
Marshall
Inverness
Pt Reyes Sta
Drakes Beach
Point Reyes
Olema
Nicasio
Burdell Mtn
Novato
Black Point
Sears Point
Skaggs Island
Mare Island
Hamilton AFB
Ignacio
Lucas Valley
Terra Linda
Forest Knolls
Lagunitas
San Geronimo
Woodacre
Sleepy Hollow
Fairfax
San Anselmo
San Rafael
Kentfield
Larkspur
Mt Tamalpais
Corte Madera
Mill Valley
Bolinas
Stinson Beach
Duxbury Point
Muir Beach
Sausalito
Belvedere
Tiburon
Angel Island
Strawberry
Rodeo
Hercules
Pinole
El Sobrante
San Pablo
Richmond
El Cerrito
Brooks Island
Albany
BERKELEY
Emeryville
Treasure Island
Point Bonita
Point Lobos
Alameda NAS
Alameda
Farallon Islands
Daly City
Brisbane
Colma
Edgemar
South San Francisco
Sharp Park
San Bruno
San Francisco International Airport
Pacifica
Linda Mar
Point San Pedro
Millbrae
Burlingame
Hillsborough
San Mateo
Montara
Moss Beach
Princeton
El Granada
Half Moon Bay
Belmont
San Carlos

PLATE


CARQUINEZ STRAIT
PABLO BAY
CATRAZ IS.
HUNTER'S POINT
SOUTH BAY
CONTRA COSTA
ALAMEDA
SAN MATEO
Vallejo
Benicia
Crockett
Rodeo
Martinez
Pinole
El Sobrante
San Pablo
Richmond
Pleasant Hill
Concord
El Cerrito
Albany
Orinda
Lafayette
Walnut Creek
BERKELEY
Emeryville
Piedmont
OAKLAND
Alameda NAS
Alameda
Oakland International Airport
San Leandro
Castro Valley
Dublin
Livermore
San Lorenzo
Hayward
Pleasanton
Brisbane
South San Francisco
San Bruno
San Francisco International Airport
Millbrae
Burlingame
Hillsborough
San Mateo
Union City
Sunol
Foster City
Fremont
Newark
Belmont
San Carlos
Redwood City
Atherton
Menlo Park
Palo Alto
East Palo Alto
Milpitas
Moffett Field NAS
Mountain View
Half Moon Bay
DREDGE DISPOSAL STUDY
AQUATIC DISPOSAL SITE
INTERNATIONAL ENGINEERING CO.,
SAN FRANCISCO, CALIF.
DR. IECO
CK.
RECOMMENDED
APPRO
DATE: MAY 74

CHAPTER VI

LAND DISPOSAL SITES

6.1 SITE IDENTIFICATION

6.1.1 General - The process of identifying land areas in the San Francisco Bay vicinity which may be available to receive dredged materials was complicated by many factors. The geographical area covered by the study is large and diverse in topography. Potential sites are located relatively close to many urban areas which subjects them to urban demands and to the authority and jurisdiction of many agencies. Because the quantity of dredged material to be deposited is large, land disposal sites must also be relatively large; such large open areas are frequently traversed by major utilities, flood control channels or other important land features. Since large open areas are rapidly becoming scarce in the Bay area, pressures on the one hand to develop them as residential or industrial properties and on the other hand to retain them as undeveloped open space may militate against their use as disposal areas. Many of the potential sites are adjacent to or near wildlife areas, which may subject their use as disposal areas to criticism.

The site identification process was essentially a process of elimination. Beginning with some basic constraints, a methodology was developed and implemented which led to the identification of a number of potential sites. The process was carried out over the entire study period to identify as many potentially available sites as possible.

6.1.2 Constraints - Several logical constraints were imposed by the Scope of Services on the site identification process at the outset of the study:

- Areas must be larger than 200 acres. This condition was included because one purpose of this study was to identify and evaluate sites capable of accommodating disposal from Bay dredging activity for 20 years (200,000,000 cubic yards ±). It was assumed that the least number of sites necessary to accomplish this would result in the most economically feasible solution.

In selecting the sites, the 200 acre minimum criterion was observed, but the more desirable sites are considerably larger, since economies accrue when development costs are spread over longer time periods and greater quantities of spoil material.

- Areas must not encompass public wildlife refuges or recreation areas or critical wildlife habitats (including marshes and mudflats). Inclusion of this constraint was predicated on the fact that landfill operations would materially, and perhaps irretrievably, change the characteristics and use of such lands.

- Areas should generally not be above the fifty-foot mean sea level (MSL) contour or below the elevation of mean higher high water (MHHW). The first constraint was imposed because of transportation economics; it is possible, however that a future study to identify potential sites above the fifty-foot elevation would be productive. The lower elevation limitation was based on regulatory agency policies affecting such areas. Several potentially promising sites are included, however, which are situated below MHHW but are behind dikes and used primarily for agriculture.

- Areas with existing development should be excluded. This constraint is self-explanatory.

- Areas should be within approximately 60 miles of any dredging site. Transportation economics dictated inclusion of this constraint.

- Although not listed in the Scope of Services, other constraints were observed during the selection process: for example, areas of excessive slope or those required for flood plain management were excluded. Imposition of these constraints eliminated consideration of areas on which the topography would render site development very costly and site operation difficult.

The feasibility of using abandoned quarries as disposal sites was also considered and a number of quarries within a reasonable distance of the

Bay were investigated. Rock quarries were ruled out after a preliminary review because of their small capacities. Sand and gravel quarries were eliminated because of the possiblity of contamination of ground water by the pollutants in the dredged materials, especially in the early stages of filling before a "blanket" of clay is built up. Also, many sand and gravel pits are in areas of ground water recharge (pits near Fremont are of this type) which would preclude their use as disposal sites.

6.1.3 Methodology - Using the above constraints as ground rules, a methodology for identifying potential sites was developed. The methodology, consisting of the following elements, was iterated over the duration of the study.

A. Basic constraints were plotted on maps covering the study area (encompasssing areas within 60 miles of dredging sites). Information for the plotting process was derived from USGS maps, road maps, city maps, aerial photographs,and other documents. Of particular value were recent (1970 and 1973) NASA photographs furnished by the San Francisco District of the Corps of Engineers. These color photographs, taken from an altitude of 60,000 feet are of extremely high resolution. They were especially useful in identifying open areas around the periphery of the Bay.

B. Sites apparently not in conflict with basic constraints were visited and given a brief field inspection.

C. Agencies and parties having an interest in the identified sites were contacted to gain further information. These included:

1. Federal Agencies

- Bureau of Reclamation
- Corps of Engineers (San Francisco and Sacramento Districts)
- Bureau of Sport Fisheries and Wildlife
- Naval Facilities Engineering Command
- Enviromental Protection Agency

2. State Agencies

- Department of Water Resources
- Department of Transportation
- Regional Water Quality Control Boards
- Department of Fish and Game

3. County Agencies

- Sonoma (Planning, Public Works, Industrial Development Flood Control)
- Sacramento (Planning, Public Works, Environmental and Conservation)
- San Mateo (Planning, Public Works, Refuse)
- Solano (Planning, Public Works, Industrial Development)
- Marin (Planning, Parks and Recreation, Flood Control)
- Alameda (Planning, Public Works, Flood Control, Real Estate)
- Santa Clara (Planning, Flood Control)
- Napa (Planning, Flood Control)
- Contra Costa (Public Works, Planning)

4. Cities

- Newark
- Fremont
- San Jose
- Foster City
- Redwood City

5. Other Agencies

- San Francisco Bay Conservation and Development Commission
- Association of Bay Area Governments
- California Coastal Commission

6. Utilities and Transportation

- Pacific Gas and Electric Company
- Southern Pacific Railroad
- San Francisco International Airport

7. Others

- Dredging Contractors
- Large Landowners
- Industrial Real Estate Brokers

Information gained from the above sources often revealed additional constraints. Also, suggestions were frequently made regarding other potential sites and additional information pertinent to site evaluation was often received.

D. Planning documents of various agencies and organizations were reviewed during the selection process.

E. Detailed inspections of sites identified through the above procedures were conducted to define significant and unique site characteristics.

6.1.4 Graphic Displays - The elimination process followed during the site selection procedure is displayed on Plates VI-1 through VI-8 which are included in this chapter.

On Plate VI-1, the 60-mile arcs from the center of gravity of dredging (near Richmond) and from the outermost dredging sites are shown. These arcs reach into Lake County on the north, east of Sacramento, and into Monterey County on the south.

Much of the area within the 60-mile arcs is, however, in mountainous or rolling country above the 50-foot contour. Plate VI-2 delineates the study area, i.e., that below the 50-foot contour and inside the 60-mile

arcs. It can be seen that there is a fairly narrow band of land of this lower elevation around the bay, extending south into the Santa Clara Valley and north into the valleys of the Petaluma River, Sonoma Creek, and Napa River. The flat land belt broadens in the Suisun Bay and Delta areas and is quite extensive along the Sacramento and San Joaquin Rivers as they drain their respective valleys. Plate VI-2 is also an index map for larger scale maps (Plates VI-3 through VI-8) which cover the greater part of the study area. The extreme easterly portions of the study area (in Sacramento, Solano, Yolo and San Joaquin counties) are not covered by the larger scale maps, because, although there are potential sites in this area, their economic feasibility is diminished because of their distance from the dredging areas in the Bay. Plates VI-3 through VI-8 delineate developed areas, areas classified as marshland, wildlife areas, recreational areas, and other pertinent features. In addition, potential land disposal sites which will be described in more detail in Section 6.2 are shown.

6.2 SITE EVALUATION

6.2.1 General - It is the intent of this section to provide information and guidelines for evaluating sites identified by current study efforts as well as sites which may become available in the future.

During the study, site evaluation proceeded with the determination and listing of significant factors pertinent to the use of sites for deposition of dredged material. In general, these factors may be grouped into technical, environmental, economic, or administrative categories. In order to fulfill the intent of the report (to provide information for the evaluation of identified and future sites), and to eliminate redundancy in the specific site evaluations, general considerations are listed first.

General considerations for site evaluation are listed by categories and may be used as "checklists". These considerations are broad and will assist not only in evaluating the initial suitability of a site to accept dredged material, but also to indicate potential problems in site development and operations.

6.2.2 Factors

A. Technical Considerations

- Slopes - Sites with excessive slope will allow varying thickness of deposition, which may cause placement and drying problems as well as future settlement problems. In the event that the dredged material is conditioned by compaction (discussed in Section 6.3), uniform thicknesses of deposited material are necessary to preclude extensive site preparation.

- Foundation Conditions - The majority of the proposed sites are located on bay mud, which has been described by Mitchell (Ref. 45) as "A medium to dark gray, soft, silty clay becoming firmer with depth, containing varying amounts of shells and organic matter. In some areas the upper part of the mud contains interbedded, thin lenses of fine to medium sand. The material is moderately sensitive to remolding, has a low undisturbed strength, is very compressible and possesses a medium to high plasticity".

Settlement and failure of fills placed on bay mud has been studied by numerous groups, and it has been found that the amount of settlement is proportional to the thickness of the mud layer. Lee and Praszker (Ref. 43) adapted the work of the U.S. Army Corps of Engineers (Ref. 36) to develop a chart showing the relationship between ultimate settlement, thickness of fill and thickness of mud which is applicable for certain specific conditions. Another chart provides the relationship between rate of settlement (primary consolidation) and thickness of mud. These charts have been used to estimate settlement that may be expected and rates of consolidation at various disposal sites situated on bay mud. Comments on expected settlements at specific sites are included in Section 6.3.4.

There is a possibility that a lateral movement or "mudwave" may form in the underlying mud due to loading of a disposal area. Such a wave could possibly change the contours of adjacent sloughs or marshes with attendant adverse effects on marsh biology; sites where this phenomenon possibly could

occur are identified under the individual site descriptions in Section 6.2.3. It is felt, however, that the rate of filling of the disposal areas will be so slow that this effect will be minimal.

Another significant foundation type is the peat which underlies much of the Sacramento-San Joaquin delta. The anticipated settlements due to loading of this type of foundation are discussed in Section 6.3.4.

- Earthquake Hazard - All of the disposal sites considered in this study are located in a seismically active area and may be subjected to severe earthquake shaking at any time. Pertinent geological data on the sites which are closest to known active faults (Petaluma River, Hamilton AFB, Fremont, and Bair Island) are discussed in Section 6.2.3 under the appropriate heading.

Following the Alaska earthquake of 1964, extensive investigations were made to determine the possible behavior of bay mud foundations when subjected to strong earthquake shaking. Seed (Ref. 44), based upon research at the University of California and on data from recent earthquakes, came to the following conclusions:

(1) Under level ground conditions, there is no evidence to indicate that the clay portion of the deposit would settle or liquefy during an earthquake.

(2) The sand seams in the clay may liquefy during strong ground motions, but this is unlikely to have any serious effect unless the liquefied layer underlies or is immediately adjacent to a sloping surface and is located at a depth permitting sliding to occur. Otherwise the only effect would be very small settlement as the pore pressures in the liquefied seams dissipated after the earthquake.

(3) Slopes and adjacent land composed of or underlain by the clay may slide during the earthquake due to the additional forces developed in them by the earthquake unless they are of sufficiently conservative design.

(4) The deformable nature of the San Francisco Bay mud will cause any deposit containing a substantial thickness of the clay to vibrate with a relatively low frequency of vibration. As a result, ground surface motions would have lower frequencies than those of adjacent areas not underlain by mud deposits.

These conclusions indicate that small embankments having low fundamental frequency characteristics would be expected to withstand seismic vibrations.

Concerning the amplification of ground motion and its effect on bay mud, Seed has pointed out that "... the performance of the Anchorage, Alaska soils is indicative of the fact that if settlement, liquefaction and landsliding are avoided, ground shaking on filled areas will not necessarily lead to any appreciable damage to appropriately designed structures during strong earthquakes."

- Drainage Conditions - Many of the potential sites are located in low, diked areas where rainfall or surface runoff from higher elevations must be controlled by pumping. In such locations, provision must be made for channels through or around the dredged fill and pumps of sufficient capacity to handle the flow. The pumping system could possibly be used in conjunction with disposal site pond dewatering systems. Holding basins to allow storm water evaporation or infiltration into the ground might also be considered. If dredged fill is placed on a site where it blocks natural drainage channels, channels of adequate capacity must be provided through or around the area.

- Access - This is one of the most important of the considerations since it has a direct bearing on the cost of disposal at a particular site. The ideal site would be one close enough to a dredging site so that it could be reached by a short pipeline from the dredge. Equally desirable would be one adjacent to a deep water channel so that hopper dredges or scows could dispose of their loads by direct pumpout with short pipelines

or by dumping into rehandling basins at the disposal site. Sites which are on shallow waterways, such as the Petaluma River and San Rafael Creek, are limited to access by shallow draft dredges and scows, which precludes the use of larger, more efficient equipment. Sites which are not close to waterways can only be economically reached by long pipelines, with attendant installation and operating problems and high costs.

- Existing Dikes - In evaluating sites with existing peripheral dikes or levees, thorough investigations of these embankments must be conducted if they are to be considered for use in retaining the fill material. Generally speaking, most existing dikes and levees in the Bay and Delta areas are of questionable quality, and should either be thoroughly inspected and repaired or should be strengthened with well designed and constructed buttresses.

- Shape - This is not a particularly important factor, since retention pond configurations can be adapted to fit a site of almost any shape. A site such as a long, narrow, abandoned railroad right-of-way, however, should be avoided.

- Effluent Discharge - Site location with respect to a discharge point for water decanted from the settling pond is extremely important. The most desirable site would be immediately adjacent to a body of water which could accept this discharge (subject of course, to the effluent meeting turbidity, salinity, and pollutant criteria of regulating agencies). An inland site could require a discharge pipeline and possibly a pumping system to return decanted water to an acceptable discharge location.

- Utilities - Most of the potential sites in the Bay and Delta areas are crossed by utilities. Relocations of small water, gas, power, and other lines do not generally pose a formidable problem when considered in relation to overall costs of the project. However, large electrical transmission lines such as those that cross the Petaluma River and Sherman Island sites, large cross country gas lines such as those crossing Sherman Island, and other large utilities must either be avoided, relocated, or protected. Some of the problems associated with major utilities are discussed in the section on development of the Delta and Petaluma sites. (6.3.8).

• Miscellaneous Improvements - Many of the potential sites are traversed by railroads or highways, which must be relocated or protected by dikes, or have existing developments of varying sizes and values. These latter facilities must be considered on a case-by-case basis and most be either purchased, removed or in some way protected.

B. Environmental Considerations - An assessment of the potential environmental effects of placing dredged spoils on land sites is an extremely important part of a study of this type. A full environmental impact statement is beyond the scope of this study; however, a fairly comprehensive although necessarily abbreviated assessment was made by the URS Research Company of San Mateo and is described in the following paragraphs. If land disposal of dredged material is implemented, a more detailed environmental study would, of course, be required.

The environmental assessment has been divided into two parts. The first includes a set of criteria which can be used to govern the process by which the environmental impact of the land disposal of dredged spoils is assessed. The criteria are briefly described in this section; the complete text is included in Appendix E. The second part of the environmental assessment is a preliminary evaluation of a number of proposed spoil disposal sites. These individual environmental assessments are included in Section 6.2.3 under appropriate headings.

The key problems in accomplishing the first part (establishing criteria) of the assessment are as follows:

• Development of Conceptual Methodology. Adequately assessing the environmental effects of man's actions is extremely complex. It is among the most difficult of the requirements that are currently mandated by law before a given major action, which involves environmental resources, can be undertaken. A central problem at present is the need to develop a methodology which is adequate to provide an orderly framework within which to identify key factors and to interrelate them in a significant way. The

information so developed must be presented in a form such that the total package meets the letter and intent of the law with respect to both form and content.

No methodology to accomplish this has been formally established by legislative action; there exist no formal qualifications for those engaging in environmental studies which are in any sense comparable to the licensing requirements for engineers and most other technical and professional occupations. This part of the environmental assessment should therefore be seen in the proper context: the methodology expressed therein is virtually unprecedented and represents essentially the state-of-the art in the field of environmental impact assessment generally, not simply as applied to the dredge spoil disposal problem.

- Adaptation of the General Methodology to the Problem of Land Disposal of Dredge Spoils. A specific task of this report was to develop criteria which can guide in the assessment of a specific class of activities, i.e., the disposal to terrestrial sites of dredged materials from San Francisco Bay. It has thus been necessary in establishing these criteria to correctly bias the respective emphasis of each section, in order to emphasize specific problem areas and to reduce consideration of unimportant side issues to a minimum.

This problem is largely reduced, in practical terms, to one of balancing the relative amounts of emphasis placed upon each of the many contributing scientific disciplines which must be called upon in the overall environmental assessment -- not an easy task if full cognizance is taken of the true extent of the complex interactions which characterize the environment and the rudiment of knowledge concerning controlling factors in instituting or mitigating environmental change.

The purpose of the second part of the assessment is essentially to identify the major environmental considerations bearing on the general suitability of each candidate site without conducting an in-depth survey

of environmental characteristics in detail. The preliminary assessments which comprise this part are intended to be precisely that - they are in no sense represented to be assessments upon which a detailed evaluation of environmental impact could be based. Rather, they are to be viewed as a means of indicating candidate sites which appear most suitable for detailed investigation through the application of the methodology of this part in the context of a thorough assessment of the environmental impact of the proposed project. The specific discussions omit detailed treatment of the major classes of impacts that are expected in connection with all sites or with the general case of land disposal of dredge spoils wherever it may take place. Such factors as the effect on water quality, general effects on terrestrial biological communities, and so on, have already been discussed in the first part establishing criteria. Application of this specific information to the particular proposed sites is not possible without the kind of detailed analysis that would be required in the course of an environmental impact statement.

An additional topic not discussed under each specific site description is the question of endangered species and their presence or absence. On-site investigations have shown that the majority of the sites include at least minor representation of senescent marsh communities, most of which are no longer subject to direct tidal action. The possibility does exist however, that in some of the site areas, representatives of species exist which are now considered to be in danger of extinction, e.g., the Salt Marsh Harvest Mouse (Reithrodontomys) or the California Clapper Rail (Rallus Californicus). It will be necessary in any environmental impact report to consider carefully the question of the presence or absence of these and other animal species at the proposed sites.

The detailed criteria which are included in Appendix E include discussions of the following subject areas:

- Climatology
- Hydrology
- Air Quality
- Water Quality
- Geology

- Terrestrial Biology
- Aquatic Biology
- Archeology
- Aesthetics
- Noise and Traffic
- Public Health
- Land Use/Population/Economy

The main thrust of the environmental assessment element of this study has involved the placement of dredged spoil on land disposal sites. In addition, if one or more of the transfer and transport plans conceptualized in this report are implemented, they should also be subjected to an environmental assessment. For example, if a rehandling basin is constructed either in San Pablo Bay or at one of the land disposal sites, significant environmental impacts would almost certainly be incurred which would have to be studied. Similarly, construction and operation of a permanent pipeline on the bottom of the Bay would be likely to pose environmental problems.

C. Administrative Considerations - Administrative considerations are those based on policy, regulation, or land use criteria of authorities within whose jurisdiction a site exists. Since the study area encompasses some highly urbanized areas and covers more than 10 counties, there are many authorities which exercise controls.

Agencies with regional authority or planning jurisdiction over land disposal include the U.S. Army Corps of Engineers, the San Francisco Bay Conservation and Development Commission (BCDC), the San Francisco Regional Water Quality Control Board (RWQCB) (or the Central Valley Regional Board in the Delta area), the State Department of Fish and Game, the Federal Bureau of Sport Fisheries and Wildlife, and the State Lands Commission. Several agencies within each county also have interests in land disposal;

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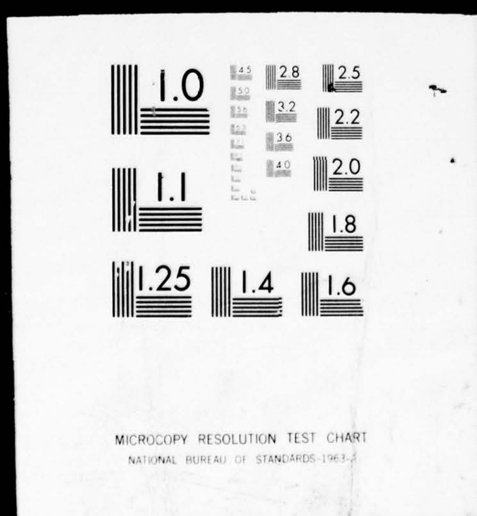

these generally include Planning, Public Works, Environmental, Conservation, Industrial Development, and Parks and Recreation elements. In addition, there are several joint-power special purpose agencies operating within the study area, such as the Association of Bay Area Governments, which exert controlling influences.

The most significant constraints of these agencies include land use regulations and policies which affect site location, development and operation, and water quality criteria which affect site operation. Certain of the regulations and policies appear to favor land deposition as the best alternative for disposing of dredged materials while others would appear to discourage it.

Specific documents obtained from each of the agencies relating to site development and operation were studied to determine administrative conditions which might affect each site.

D. Economic Considerations

- Site Location - This factor has two economic impacts: first, the closer the site to a dredging project, the less the transportation cost in reaching the site, and second, the farther away from urban areas, the less the site acquisition or use cost. Site costs in the relatively undeveloped North Bay and Delta areas, for example, may be in the neighborhood of $1000 per acre, while those near developed areas may be as high as $12,000 per acre. These figures allow conceptualization of potential trade-offs between land values and additional transportation or land enhancement costs.

- Size - Certain basic costs are associated with the development of each site; the larger the site and the more material that can be accommodated, the less the basic cost per cubic yard handled. Approximately 1613 cubic yards of material can occupy one acre of land one foot deep. A 200-acre site filled to a depth of 10 feet would accommodate approximately 3,226,000 cubic yards assuming a 1:1 ratio of disposal area volume

to shoal volume*; this amounts to 1.6 percent of the 200,000,000 cubic yards anticipated to be generated over the 20-year study period. It would require one 12,400 acre site, 10 feet deep, to accommodate all the anticipated material. Although acquisition and development costs would be greater for the larger site, the costs would be amortized over a much longer time and for a greater volume, and would show a significantly lower unit cost when compared to small sites.

- Physical Characteristics - Adverse slopes, narrow shapes, difficult access conditions, lack of adequate dikes, or unusual drainage problems may significantly increase site development and operation costs.

- Existing Improvements - Utilities, such as transmission lines, gas lines, pipelines, flood control structures, etc., that may have to be relocated or otherwise modified will affect site development costs. Buildings, railroads and other facilities will also increase costs if relocation or protection is required.

6.2.3. Specific Site Evaluations

A. General - The study area has been divided into six sub-areas as follows:

- South Bay (Plate VI-3)
- Central Bay (Plate VI-4)
- North Bay (Plate VI-5)
- Petaluma - Sonoma - Napa (Plate VI-6)
- Suisun Bay - Delta (Plate VI-7)
- Fairfield - Dixon (Plate VI-8)

Sites in these sub-areas which have been identified during this study are described and evaluated in the following paragraphs. The site numbers correspond to the numbers on the drawings.

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* This ratio is on the conservative side: as will be noted later, for unprocessed dredged material it will be closer to 0.6 to 1.

The purpose of the following sections is to disclose significant factors affecting the feasibility of using each site as a disposal area. In each instance, available pertinent information is provided. Additional information was developed for the Petaluma River and Sherman Island Sites (Nos. 8 and 13 respectively) because these sites appear to be the most feasible of the sites identified. This information is provided in Section 6.3.

B. South Bay (Plate VI - 3) - This area is marked by high urban development, not only in the foothills and flatlands of the San Francisco Peninsula, but in the burgeoning, formerly agricultural lands of Santa Clara and Alameda Counties. Although there is some land available which meets the criteria for land disposal, it is in demand for either residential and industrial development or for preservation as "open space". Consequently, the price of land in these areas is considerably higher than that of comparable land in areas farther from centers of population.

The South Bay is characterized by mudflats and marsh areas around its periphery and diked-off areas used presently or in the past for production of salt. The San Francisco Bay Conservation and Development Commission (BCDC), which has jurisdiction over submerged lands, tidelands, marshlands, salt ponds and managed wetlands, has an adopted policy (Ref. 14) which requires maintenance to the fullest possible extent of marshes and mudflats and maintenance of salt ponds in their present state and wetlands in their present use. BCDC's policy also encourages the return of managed wetlands or salt ponds to open water if their owners desire to withdraw them from their present uses. A large part of the South Bay marsh, open water and salt pond area is included in the San Francisco Bay National Wildlife Refuge, established in 1972.

The agencies which have jurisdiction over flood control channels into the South Bay have the continual problem of keeping the outlets of the channels open into the perennially silting Bay. While flood control officials are primarily interested in finding disposal sites for their own dredging requirements, it appears that they would be interested in accepting additional material if they could be assured that their own needs would be met.

Four potential sites have been located in the South Bay area: No. 1, in the Alviso-Milpitas area; No. 2, near the Fremont Sky Sailing Airport; No.3, in north Fremont; and No. 4, at Bair Island-Redwood Shores. Other areas worthy of brief mention are as follows:

- Moffett Field Naval Air Station was investigated in a Navy study (Ref. 13), which indicated that there is a potential disposal site in an abandoned salt pond on the station. Because of its small size, remoteness from dredging sites, and possible environmental constraints, it is not considered a viable site.

- Several small open areas exist between Moffett Field and Palo Alto, near the Bay. These were also rejected because of their small size, distance from major dredging sites and access problems.

- A diked area of over 500 acres to the south of the Palo Alto Golf Course and east of the Bayshore Freeway was considered but rejected when found that it acts as a flood control basin. Also, this site was recently identified by the Palo Alto City Council as a wildlife preserve.

The four most promising sites are discussed below:

(1) <u>Alviso-Milpitas (Site No. 1)</u>

Area: 2550 acres

Capacity: 41,000,000 cubic yards (10-foot depth - uncompacted)

This site includes adjacent areas which abut the wetlands of the Alviso area. Typical of much of the vicinity, the site is relatively low and is protected from the Bay by dikes. Site elevations range from approximately Mean Higher High Water (MHHW) to about 20 feet above sea level. About 15 percent of the site is below MHHW.

Although this site is flat, dry land, primarily used for agriculture, its potential for flooding is high. This potential has increased because of

general land subsidence experienced in the area due to ground water extraction. Several interested groups, including the City of San Jose, which exercises jurisdiction over and owns a portion of the site, appear favorably inclined toward some filling to reduce the threat of flooding.

The site is within the jurisdiction of Santa Clara and Alameda Counties; it is not within the jurisdiction of BCDC. The Association of Bay Area Government (ABAG) has designed the area as permanent open space. City plans show partial urban development in the area. Utilization of the site may be affected by the litigation in process regarding incorporation of the Alviso area.

Access to the site would almost certainly be by a pipeline which would have to traverse wetlands. Development and operation of the site could be expensive due to access difficulties and the fact that it is composed of separated areas. On the other hand, if the property owners are anxious for fill, this expense may be offset. Water from site operations could be returned to the Bay through local waterways; hydraulic characteristics of these waterways would have to be maintained in the interest of flood control. There could be problems from an environmental standpoint because of returning effluent to the Bay through wildlife areas. The proximity of the site to Guadalupe Creek and the San Francisco Bay National Wildlife Refuge would both be important topics in an environmental impact statement (EIS). Proximity to Routes 17 and 237 would have to be evaluated from an air quality and aesthetic standpoint. There is some potential for archaeological artifacts.*

(2) <u>South Fremont (Site No. 2)</u>

Area: 1950 acres

Capacity: 31,000,000 cubic yards (10-foot depth - uncompacted)

* The primary concern from an archaeological standpoint in the Bay area is for evidences of settlements occupied by native Americans. Criteria for rating the archaeological potential of the various land disposal sites included: proximity to locations where remains have been found in the past, and such items as proximity to food sources (mud flats, woodland areas, etc.) and proximity to locations sheltered from tidal action, wind, and other elements.

This site ia adjacent to the Sky Sailing Airport and bounded on the west by wetlands and by Highway 17 on the east. The site is subject to flooding (elevation ranges from just below MHHW to plus 20 feet with about 20 percent below MHHW) and presently does not appear to be used except for grazing.

The site is within the city limits of Fremont in Alameda County, and is subject to control by both the City and County. These two agencies, as well as ABAG, have designated portions if not all of the site as permanent open space. The site is not under BCDC jurisdiction.

Site access would probably be via pipeline which would cross wetlands at some point. Return water flow from site operation could be routed along one of the local waterways, although this might draw criticism on environmental grounds.

Periodic flooding of the area is attributed to general land subsidence as well as poor quality dikes separating the area from adjacent wetlands. More productive use of the lands may be realized if they are filled. Soil in the site area has low permeability and poor natural drainage characteristics with a moderate consolidation potential. A railroad and power transmission lines cross the site.

There appear to be many environmental questions surrounding the potential uses of this site; the Conservation Element of the Fremont General Plan includes the site as an "Environmental Issue Area." The site is not far from the San Francisco Bay National Wildlife Refuge, and its potential influence on the Refuge would have to be carefully evaluated. The effect of effluent discharge to and potential mudwave effects on Mowry Slough should to be carefully evaluated.

The site has potential archaeological value. Since dredged material would have be transported some distance across mudflat and salt marsh communities, consideration of the potential effect of a pipeline break would be essential.

(3) North Fremont (Site No. 3)

Area: 1800 acres

Capacity: 29,000,000 cubic yards (10-foot depth- uncompacted)

This site is adjacent to the Coyote Hills Regional Park and is surrounded by housing developments. It is currently a highly productive agricultural area.

The site is primarily within the City of Fremont in Alameda County. Both ABAG and Fremont have designated the area as open space, although there appears to be pressure to develop the area. In addition, Fremont has designated the site a "study area" for potential acquisition as an open space area. The site is not under BCDC jurisdiction.

Access would most likely be by pipeline, which would of necessity cross wetlands. Return water from site operations could be discharged down Alameda Creek.

The site is traversed by roads, power transmission lines, a railroad, and a major flood control channel. The flood control channel levees are quite high relative to the site, which ranges from approximately 5 to 20 feet above sea level. Portions of the site are used by the Alameda County Flood Control District as holding areas for surface runoff from upland areas. The holding areas are also below the top of the channel leeves. Development of the site would require consideration of alternative means to handle the flood water.

Fertile agricultural soils with good drainage characteristics and moderate subsoil permeability typify the site. The Open Space Element of the Fremont General Plan refers to the area as the "last of undeveloped prime agricultural land" in the area.

The site is shown on a Conservation Element map of the Fremont General Plan as an environmental issue area. Although the area involved is mostly farmland, there is evidence of wildlife use. The utility of the area for indigenous wildlife has been reduced by agricultural activities which have significantly modified native habitat. The proximity of the site to the Coyote Hills Regional Park may be a cause of concern among interested groups. *There is a possibility of mudwave shallowing of the* adjacent slough (Coyote Slough), with potential negative impacts. The proximity of the site to Highway 17 and residential areas may pose odor and aesthetic problems.

Runoff water discharged to the Bay may create problems with respect to turbidity and BOD because of the relatively poor exchange rates in this part of the Bay.

This site may have archaeological value although its importance has not been evaluated. There is an additional disadvantage in the distance from the discharge point to the disposal area, with the consequent necessity of traversing significant marsh and mudflat habitats during the installation of spoil pipes.

Because of its desirability as agricultural land and for other potential uses, the value of the land is quite high, from $6000 per acre on the western side to $10,000 to $12,000 per acre near the freeway. It is one of the closer of the sites to an active fault; its eastern margin is located approximately 3 1/2 miles west of the Hayward fault. It could be subject to shaking during movement along this fault.

(4) Bair Island (Site No. 4)

Area: 2500 acres

Capacity: 19,000,000 cubic yards (8 ft depth - uncompacted)

Located between the Port of Redwood City, the Redwood Shores development, Highway 101 and the Bay, this island site is owned by Mobile Oil Estates Ltd.

It has been the subject of controversy; a portion was recently granted to the State as a game refuge in an effort to clarify title and use potential. The developer has included in his planning the provision of a buffer zone between the residential/commerical portion of the area and the wildlife area.

Having successfully placed dredged material as fill for their Redwood Shores project, the owner-developer of the site is willing to accept dredged material at this site, as well as a small quantity at the Redwood Shores development.

The site is within the jurisdiction of Redwood City, San Mateo County and BCDC. The City, County, and ABAG open space plans show the site as an urban area with permanent open space (parks and beaches) around the perimeter. BCDC jurisdiction is only along the 100-foot shoreline band which is shown as tidal marsh on the Bay Plan with specific mention of a heron rookery. The site is entirely below MHHW.

The Redwood City Goals for Waterfront Development (Ref.30) state under the heading "Goals for Residential Development" that "... Residential development will only be allowed on Redwood Peninsula and Bair Island" and under the heading "Goals for Recreational Development" "... Reserve a large multi-acre site on Bair Island for a regional park..." The developer's plan is in conformance with these goals.

Access to the site would probably be by pipeline with direct effluent return to the Bay. Because of its proximity to the port of Redwood City, this site would appear to be a logical choice to receive dredged materials generated by this port and possibly others in the vicinity.

This is also one of those closest to an active fault; it is about 6 miles east of the San Andreas Fault and could be subject to earthquake-induced shaking.

Remnants of salt marsh communities and salt ponds are included within the Bair Island site. The site is an area of high wildlife use, particularly for waterfowl. Use of the area for dredge spoil disposal purposes would reduce available wildlife habitat in a part of the south Bay where such habitat is already scarce.

A potential may exist for extrusion of the underlying mud at Bair Island as a "mudwave". This could result in the shallowing of the adjacent Steinberger Slough, with decidedly negative consequences for the vertebrate and invertebrate fauna of the slough and adjacent shore areas.

C. Central Bay (Plate VI - 4) - The Central Bay is characterized by dense urbanization and very little space which could be feasibly used for dredged spoil disposal.

Only one area, at Bay Farm Island (Site No. 5), was considered worth identifying as a potential disposal site. Some other areas which can be briefly commented upon are:

- An area of 185 acres on the site of the old garbage dump south of Candlestick Point. This is a marginal site because of its high elevation, small size and surrounding developments. The south end of the site is shown by BCDC as a proposed aquatic park; the San Mateo County Open Space Element of the General Plan indicates future urban development in the area.

- West of the Hayward Airport are some diked salt ponds, comprising some 650 acres, which have been considered for development as residential and industrial property. This area is not shown on BCDC's plan as being slated for any particular future use, but is of doubtful potential because of its relatively small size, its possible use as a managed wetland or wildlife area and its distance from dredging centers. Planning agencies have designated this area for eventual return to tidal action.

• The Navy study (Ref. 13) indicates that a potential disposal site exists at the Seaplane Basin on the Alameda Naval Air Station. It is estimated that 3,700,000 cubic yards of unconditioned spoil may be accommodated at this location. It is doubtful, however, that the BCDC would approve of even this small reduction of the Bay's water surface.

(1) Bay Farm Island (Site No. 5)

Area: 900 acres

Capacity: 14,500,000 cubic yards (10-foot depth - uncompacted)

This portion of Bay Farm Island was reclaimed from previously submerged Bay land, and is now above the MHHW line. Much controversy exists over potential use of the area, due to local expansion policy and the proximity of the Oakland Airport.

The site is located within the City of Alameda in Alameda County. Neither the City nor the County has any particular policy or regulation which would adversely affect the placing of dredged material on the site. BCDC has jurisdiction over a 100-foot wide shoreline band which is indicated as a shoreline park in the BCDC Bay Plan. BCDC has also indicated that the site may be suitable for airport-related industry. ABAG has shown the site developed except for open space along the waterfront. The owner-developer of the site has stated that very little if any additional fill will be required for the development planned. Since work on the development may start soon, very little time would be available to place fill.

Adjacent to Bay Farm Island are approximately 400 acres of undeveloped land located on the Oakland Airport. Airport officials indicate that development of this area is also imminent and that, because of the nature of the planned improvements, they cannot accept dredged materials as fill.

Access to this site could be by pipeline or water with return effluent flow directly to the Bay.

The portion of the site on Bay Farm Island has already been subjected to filling, with consequent prior subjection of the local biological communities to significant disturbance. There is some residual marshland in the airport portion of the site which is intensively used by native bird populations.

The possibility of some mudwave shallowing exists on the south side of San Leandro Channel. Proximity of the site to the open waters of the Bay places importance on runoff water control.

Because of nearby residential areas, added importance must be placed on methods of restricting landside access; the operation may consitute an attractive nuisance for children with concomitant risk of accidental drownings or other personal injuries related either to the impoundments or to construction equipment. Aesthetic problems and odors may constitute a source of potential difficulties, although it should be possible to ameliorate these through appropriate design and operational controls.

The proximity of the site to a high-use airport may affect the ultimate potential uses of the site after filling; particularly careful planning concerning this ultimate use will be required, as well as close coordination with the land-use planning agencies with an interest in the site.

D. North Bay (Plate No. VI - 5) - This area is characterized by the densely populated East Bay cities, the rugged southern Marin hills,and the shallow, marshy, San Pablo Bay area. A large portion of the marshes and mudflats on the north side of San Pablo Bay are included in the San Pablo Bay National Wildlife Refuge.

There appear to be no viable sites on the west side of the Bay between the Golden Gate and the area just south of Hamilton Air Force Base, either because of the rugged terrain or urban development. Sites in the Hamilton AFB vicinity will be discussed later.

The area between Berkeley and the Carquinez Strait is not feasible for disposal sites mainly because of intensive urbanization or rugged topography. A few small areas such as the Richmond dump, Point Pinole, and Wilson Point were rejected because of their small size.

The Mare Island Naval Shipyard is of peripheral interest because it has been operating its own dredging and disposal system for a number of years. A small dredge, operating in the Mare Island straits, pumps directly across the island through permanent pipelines to disposal areas on the west side. The Navy study (Ref. 13) estimated that if the existing dikes are raised 4 feet and strengthened,a total of 3,500,000 cubic yards could be accommodated. There are marshland areas on the station which could, if developed, increase the total to 7,000,000 cubic yards. This latter proposal would undoubtedly meet with strong criticism from BCDC and other agencies. Because of the Navy's requirements for disposal of its own dredge spoils, Mare Island was not considered to be a viable site for disposal of material from other sources.

(1) Hamilton AFB South (Site No. 6)

Area: 1150 acres

Capacity: 18,500,000 cubic yards (10-foot depth - uncompacted)

This site, south of Hamilton AFB, is bounded by Gallinas Creek, the airbase, the Northwestern Pacific Railroad and the Bay and is protected by dikes. A portion of the site includes Marin County's McInnis Park while other parts are used as grazing land.

ABAG has designated this area as one of urban development in their Regional Open Space Plan, Phase II, while BCDC's Bay Plan notes the possibility of a major park even though the site is out of BCDC jurisdiction.

Access to the site would most likely be via pipeline and operation effluent could be returned directly to the Bay. Two power transmission lines cross the site. Flood control measures may be required for Gallinas Creek. The site is almost entirely below MHHW.

The site is adjacent to marshland and supports moderate to high wildlife use. The potential for mud wave shallowing of the bayward marsh and Gallinas Creek exists. The proximity of the site to the bayward marsh increases the danger of damage to the marsh by accidental discharge of polluted water or spoils from the operation. The effect of any potential discharge to Gallinas Creek would be a major topic of concern in an EIS.

The site has some archaeological potential. The presence of some nearby residences could require adoption of operational controls considerably more restrictive than in the case of more rural sites.

(2) Hamilton AFB North (Site No. 7)

Area: 3850 acres

Capacity: 62,000,000 cubic yards (10-foot depth - uncompacted)

This site is composed of adjacent areas on both sides of Highway 37 to the northeast of Highway 101 in Marin County. The areas are presently used for grazing and agriculture. It is also almost entirely below MHHW.

Marin County does not indicate any land use constraints on the areas which would affect filling except that the area adjacent to the Bay at the north of Novato Creek is a flood plain area. ABAG designates the area for urban development while BCDC, which has jurisdiction over the shoreline portion only, shows a section of the site as a potential lagoon and park area. It should be noted that this site surrounds the coummunity of Bel Marin Keys.

Access to the site would most likely be through pipeline with return water effluent being discharged to the Bay via Novato Creek. Right-of-way

would have to be provided for pipelines jacked under Highway 37 or along the Novato Creek Highway crossing to facilitate operations in the area northwest of the highway. Extensive flood control measures would be required on Novato Creek to prevent flooding of both the filled area and the adjacent lands. Two power transmission lines traverse the site.

Sites 6 and 7 are among the closest to an active fault (approximately 4 miles west of the extended Hayward-Healdsburg-Rodgers Creek fault system), and could be subject to seismic activity.

As noted earlier, the site is primarily farmland, with some adjacent sloughs and marsh. The area supports moderate to high wildlife use. Its proximity to the San Pablo National Wildlife Refuge is a source of potential difficulties with regard to the project's effect on wildlife. There appears to be a potential for mudwave shallowing of sloughs, creeks and the bayward marsh. A possibility of archaeological remains exists in the area, although few have been found. The proximity of the site to Novato Creek, the marshlands and the Bay increases the danger in case of accidental spills, but reduces the problem of material transport over critical marshland and mudflat habitat.

E. Petaluma - Sonoma - Napa (Plate VI - 6) - The three main watercourses of this area, the Petaluma River, Sonoma Creek, and the Napa River, drain into the northern end of San Pablo Bay. Large acreages of former marshland have been diked off in the past near the mouths of these rivers for agricultural use. Many of these areas have potential value for land disposal.

Three major potential areas were identified: Site No. 8 in the Petaluma River drainage basin, Site No. 9 in the Sonoma Creek drainage and Site No. 10 in the Napa River drainage. Other sites worthy of note are:

- Skaggs Island - Identified in the Navy study (Ref. 13) as a prime site for disposal of dredged material, this site has a capacity of 15,200,000 cubic yards of unconditioned fill or 30,400,000 cubic yards of conditioned fill.

It appears to be a good potential site if agreement can be reached with the Navy for its joint use. Its use would be subject to approval by regulatory agencies (Corps of Engineers, BCDC,etc.). The BCDC Bay Plan envisions its use as a wildlife area or water-oriented recreational complex if the Navy ever relinquishes control.

- Napa Marshes - This area, located between the Napa River and Napa Slough on the north shore of San Pablo Bay, was orginally a natural marsh and delta formed by the Napa River. Today the greater portion of the area consists of a series of salt ponds. It has been deemed an excellent wildlife habitat in spite of its present intensive use by the salt industry. The Solano County Resource Conservation and Open Space Plan states that, pending the results of an on-going study,the policies and recommendations applying to the Suisun Marsh will be applied to the Napa Marsh. These policies and recommendations protect and preserve the marsh environment. Napa County's policy (Ref. 34) is to "return salt extraction ponds to marshlands or other non-urban uses for recreation, fisheries and wildlife habitat at the termination of salt extraction activity." The BCDC Bay Plan shows the marshes to be managed wetlands, except for the eastern end of Island No. 1, which is unassigned.

Since adminstrative policy is strongly in favor of keeping the Napa Marshes in their present state or returning them to use as wildlife habitat, they were not considered further as potential disposal sites.

(1) Petaluma River Area (Site No. 8)

Area: 8600 acres

Capacity: 139,000,000 cubic yards (to elev. + 10 - uncompacted)

This site is composed of three sub-areas: (1) an area of 5700 acres bounded on the east by the Lakeville Highway, on the west by the Petaluma River, and on the south by San Pablo Bay; (2) an area of 1300 acres on

the east side of the Petaluma River between Petaluma and Lakeville, west of Highway 16; and (3) an area of 1600 acres on the west side of the Petaluma River around the Marin County Airport. The areas are protected by dikes and used for agricultural or grazing purposes. About 80 percent of the area is below MHHW.

Sub-area (1) is probably one of the most promising for land disposal in the Bay area from the standpoints of location and size, and it was chosen for detailed study in the section on site development and operation (Section 6.3).

Site access could be via either dredged channel or pipeline with operations effluent returned to the Bay by the Petaluma River. Portions of this site are below MHHW while the remainder slopes upward to elevation + 10 in the inland direction. Three transmission lines and a railroad traverse the site. There is concern over flood control in the site area although no restrictions have yet been imposed.

This site is virtually all farmland at present with minimal apparent wildlife use over most of its extent. The potential for mudwave shallowing of the Petaluma River or nearby marshes may exist, although this factor is difficult to evaluate without more detailed data. The potential impact of accidental spill of either dredged materials or excess water into the Petaluma River is a hazard which should be evaluated. Present data are not sufficient to demonstrate the magnitude of the effect, if any, that such discharges would have.

There is some potential for archaeological remains, although few have been found to date. Few other identifiable environmental problems would appear to exist at this site given presently available information, particularly if adequate safeguards are employed with regard to control of surface water runoff from the site.

Sub-area (2), in the same drainage area as the first, is adjacent to the Petaluma marsh and is protected by levees along the river. Material would be transported by pipeline from the San Pablo transfer point or

The lower Petaluma River site transfer basin. Technical and economic considerations are similar to those of the lower Petaluma River site, although costs would be higher because of the longer transport distance.

Sonoma County has considered both the upper and lower areas in a draft flood plain zoning plan. It was proposed that the upper area be zoned "F-1" (Primary Flood Plain) and the lower area "F-2" (Secondary Flood Plain). "F-1" zones cannot be obstructed if the flood hazard will be increased by so doing; "F-2" areas are subject to flooding but are not required to carry off or store flood waters. These definitions would tend to allow the use of the lower site for fill disposal but not the upper. The proposed flood plain zoning has not been adopted as of this writing, however.

The upper Petaluma site could be subject to criticism as a disposal site because of its proximity to the Petaluma Marsh.

Sub-area (3), in the Petaluma River drainage area, adjacent to the Marin County Airport, is low and flat, protected by levees, and traversed by several small creeks and ditches. It has moderate to high wildlife use. Its proximity to the San Pablo Bay National Wildlife Refuge is a factor which will require careful evaluation. Here again, a potential exists for the mudwave shallowing of sloughs, creeks, and marshlands. There is a low to moderate potential for archaeological remains. The nearness of the site to US 101 and the County Airport will affect ultimate land use, and put a premium on close coordination with those responsible for land-use planning in the area.

Neither of the counties in which the site areas are located (Sonoma and Marin) appear to have any regulations or policies which would adversely affect filling of the Petaluma River sites. ABAG has designated most of the area as permanent open space with a small amount for controlled development. BCDC exerts control over the wetlands along the periphery of the sites only,but has noted the potential for water-related industry for the area to the north of the Petaluma River mouth.

The eastern part of the site is crossed by the Healdsburg-Rodgers Creek fault. This fault system appears to be an extension of the active Hayward fault. Surface fracturing has been observed along the Hayward and Rogders Creek segments and field investigations along the Healdsburg fault have been planned by the U.S. Geological Survey. Tectonic creep is known to be occuring along the Hayward fault, but has not been observed along the Healdsburg-Rodgers Creek segment. This does not necessarily indicate, however, that tectonic stresses are low in the area.

Foundation conditions at Petaluma site will be discussed in greater detail in Section 6.3.

(2) Sonoma Creek Area (Site No. 9)

Area: 10,600 acres

Capacity: 171,000,000 cubic yards (10-foot depth -uncompacted)

This area includes Tubbs Island, which is adjacent to the lower Petaluma River site, areas along Sonoma Creek and adjacent sloughs, and the northern part of Skaggs Island. About 90 per cent of the area is below MHHW.

Tubbs Island is a diked agricultural area comprised of 2600 acres and is similar to the lower Petaluma River site. The southwest tip of the island is part of the San Pablo Bay National Wildlife Refuge; the rest of the island is low, flat and protected by levees around its periphery. It is used mainly for agriculture except for the areas which are too wet for crops. Technically and economically it is a good prospect for a disposal site because of its proximity to the center of gravity of dredging in the Bay. There are no known restraints other than the facts that it is entirely below MHHW and near to the wildlife refuge. Access to the site would probably be by pipeline from the Petaluma River site or directly from the San Pablo transfer station.

The site is composed primarily of farmland and older marsh. It is a high wildlife use area, considered to be of prime importance by some environmentalists. Land title to the territory in question is partly in the hands of some conservation groups, who may be expected to oppose any plan for dredge spoil disposal at the site. It is immediately adjacent to the San Pablo Bay National Wildlife Refuge, which may be an additional source of conflict with respect to use of the area for dredge spoil disposal.

Potential exists for mudwave shallowing of Tolay Creek, numerous sloughs, and adjacent marshlands; archaeological potential of the site is low to moderate. The utility of the site suffers from the possible long transmission distance across mudflats and marsh; possible disturbance of the biologic communities may be severe in the corridor along the spoil pipeline route. The hazard to the nearby wildlife refuge and the mudwave shallowing of adjacent slough and marshes can be expected to require detailed attention in any EIS prepared for the site.

The sites along Sonoma Creek and adjacent sloughs are potentially good sites from technical standpoints, except for the fact that they are broken up by numerous waterways which would hinder development of settling ponds.

The Northwestern Pacific Railroad traverses the Sonoma Creek area in a north-south direction. The ABAG Regional Open Space Plan, Phase II, designates the sites as permanent open space; BCDC has no jurisdiction of the sites with the exception of the 100-foot shoreline strip along the sloughs and creeks traversing the area. Sonoma County has no available plans covering the area at this time.

Access to the site would probably be by pipeline while return water effluent could be discharged through the local waterways. Flood control measures may have to be incorporated in site development plans. Perimeter dikes would have to be established for each separate operating area in the site in order to preserve the local waterways.

The site in the Sonoma Creek drainage area supports moderate to high wildlife use, and there would appear to be potential for mudwave shallowing of adjacent sloughs. Archaeological potential is low to moderate. The aesthetic impact of the landfill operation, as seen from the highway which traverses the area, will have to be evaluated.

The long transmission distance across mudflats and marsh is a negative factor which will require extensive evaluation. The proximity of the sites to sloughs, Sonoma Creek and the Napa River increases the potential for damage through accidental spills.

The northern portion of Skaggs Island (1000 acres) is similar to Skaggs Island itself, being a diked agricultural area. It is similar to the Petaluma and Tubbs Island sites in many respects, but the cost of development would be greater because of longer transport distances.

(3) Napa River (Site No. 10)

Area: 1250 acres

Capacity: 20,000,000 cubic yards (10-foot depth - uncompacted)

Across the Napa River from the Napa Marshes is an area between the City of Vallejo and the Napa County Airport which is low and flat; individual sections of this area are protected by levees. It is entirely above MHHW. The land is generally used for grazing.

BCDC has no jurisdiction over the area, although it has designated the area between the proposed site and the Napa River as salt pond or managed wetland.

Napa County apparently has no restrictions on using the site for dredged material filling. ABAG designates urban development in the area and, in fact, a residential community is encroaching the site from the east.

Site access would be via the Napa River, for shallow draft vessels, or by pipeline. County flood control engineers indicate there is a potential for flooding at the site which filling could eliminate. A power transmission line and a railroad traverse the site.

Wildlife use is high; the site is adjacent to the Napa River wildlife area. There is a significant potential for mudwave shallowing of adjacent marshlands and sloughs. Archaeologic potential in the area is moderate to high.

Its proximity to the Collins residential area raises the importance of aesthetic questions. Proximity to the Napa River increases the importance of preventing accidental spills of either spoils or unreclaimed runoff water because of potential adverse effects on indigenous and anadromous fish.

F. Suisun Bay - Delta (Plate VI - 7) - This area is characterized by the heavily industrialized northern Contra Costa County coastline, the Suisun Marsh, and the Delta islands.

From Carquinez Straits to the Benicia-Martinez Bridge, the topography on both the north and south sides of the strait is too rugged to provide disposal areas of any importance.

On the south side of Suisun Bay and the San Joaquin River, the area between Martinez and the Delta is either presently highly developed or zoned for future industry. Much of the land near the water is marshy and unsuitable for disposal areas. There are some undeveloped flat areas in the Martinez-Pittsburg-Antioch vicinity, but because of their relatively small size, they were not considered as good prospects, with the exception of the Avon site (No. 11).

The Suisun Marsh is recognized as being of vital importance to wildlife and wildlife-related recreation. To quote the Solano County Open Space Plan (Ref. 16), the 84,000-acre Suisun Marsh is "undoubtedly the most complicated and fragile natural environment within the County."

Potential sites in or bordering on the Marsh will be subject to intensive environmental scrutiny if they are proposed for definite use as land disposal areas.

Other than the Avon site, two sites in the Suisun Bay-Delta area are considered to have good potential as land disposal sites: Montezuma (Site No. 12) and Sherman Island (Site No. 13). Other sites worthy of note are as follows:

- The Naval Weapons Station at Concord was identified in the Navy study (Ref. 13) as having a total capacity of 5,750,000 cubic yards. Because a large part of the proposed area is in the tidal range, it probably would be unacceptable to regulatory agencies.

- An area of 1600 acres on Grizzly Island, south of the Potrero Hills, has low potential as a disposal site because of its location adjacent to the State Game Management area and proximity to marsh areas. It should be noted that a proposal by Envirosol, Inc., to barge garbage to a site in the Potrero Hills has recently been the subject of criticism from environmentalists because of potential detrimental effects on the Suisun Marsh.

Description of the three sites in the area with the best potential for use as disposal areas follow:

(1) <u>Avon (Site No. 11)</u>

Area: 400 acres

Capacity: 6,500,000 cubic yards (10-foot depth - uncompacted)

The only potential site along the north Contra Costa County shoreline between Martinez and Antioch larger than 200 acres is about one and a half miles east of the intersection of I-680 and Waterfront Road. It contains about 400 acres of diked flatland which has potential as a

disposal area for material dredged from the ship channel in Suisun Bay, but would only have a short life because of its small size.

Dikes around the site prevent flooding and allow a small amount of native grass to flourish. It is above MHHW. The site is immediately south of the Southern Pacific main line and is surrounded by industrial development.

The draft Open Space Conservation Plan of Contra Costa County contains no apparent restraints on a dredged fill operation at the site. ABAG designated the site as urban developed land, while BCDC shows it as a potential water-related industrial site.

Access to the site could be by pipeline which would traverse wetlands and return effluent could be discharged into the adjacent Pacheco Creek.

The site has moderate wildlife use. Potential for mudwave shallowing of adjacent marshland is low but not insignificant, based solely on superficial observations to date. Archaeological potential is low. The site is adjacent to a road and some nearby residential areas could be affected. The transmission of spoils over a long distance through mudflat and marshland would be required and is a potentially negative feature of the site.

(2) Montezuma (Site No. 12)

Area: 3000 acres

Capacity: 44,000,000 cubic yards (to elev. + 10 - uncompacted)

One of the better sites from many aspects including size, location near a deep water channel, flat topography, etc., is the Montezuma site. It is a diked agricultural area west of the town of Collinsville, bounded on the east by the 50-foot contour line and on the west by Montezuma Slough, which is adjacent to Suisun Marsh. About 80 percent is below MHHW.

Solano County has designated a portion of this site as agricultural, grazing and watershed land, with the remainder as industrial, in the County's Resource, Conservation and Open Space Plan. This plan notes the importance of this area as one of the few remaining areas along the river where water-related industry can be located. The State Department of Fish and Game has proposed a buffer zone around the Suisun Marsh, which includes the site. ABAG designates the site as urban developed or controlled open space land, while BCDC's Bay Plan shows the site potentially available to water-related industry. The joint owners of this property are the Southern Pacific Railway Company and the National Steel Corporation.

Site access could be by a direct water route or a pipeline; effluent water could be returned via Montezuma Slough or the Sacramento River. Crossing the site is an abandoned railroad line which may be reactivated should the site be developed industrially. The site slopes gently upward toward the Montezuma Hills from the dike which separates it from the Montezuma Slough.

The site has moderate to high wildlife use. It is adjacent to the Suisun game mangement area and to several waterfowl clubs. There is the potential for mudwave shallowing of the adjacent slough. Archaeologic potential is moderate. Effluent discharges to the slough and marsh areas nearby may produce negative environmental effects which would figure importantly in an EIS.

(3) <u>Sherman Island (Site No. 13)</u>

Area: 10,000 acres

Capacity: 317,000,000 cubic yards (to elev. +10 - uncompacted)

The Delta Islands are prime sites for disposal of dredged material because of their size and proximity to water transport. Undesirable features are the great distances from dredged sites and possible foundation problems.

As a representative Delta Island, Sherman Island, the closest to the dredging sites, was chosen for analysis. Other adjacent islands, such as Jersey, Bethel, Bradford, Webb, Twitchell, and Brannan, would be very similar but would require longer transport for the dredged material. Sherman Island is shown on Plate VI-11 and its development is described in Section 6.3.

The soil of the Delta Islands is sediment and peat, and it is productive agricultural land. Problems associated with adding the weight of the dredged material and building dikes on the islands are covered in Section 6.3.

BCDC and ABAG have no jurisdiction in the area. The Sacramento County Comprehensive Zoning Plan classifies Sherman Island as AG-20 and AG-80 (agricultural). There do not appear to be any administrative constraints to the use of the island for disposal of dredged fill.

As will be noted in Section 6.3, Sherman Island is covered with utilities of many types. Three high voltage power lines cross the island, as well as major gas transmission lines. The island is also dotted with gas wells. Highway 160,which crosses the island in a north-south direction, is scheduled to be improved soon.

Access to the site could be by hopper dredge or bottom dump scow to a rehandling basin on the south side of the island, by direct pumpout of scows, by hopper dredges moored in the channel adjacent to the island or by pipeline.

In addition to their high values from an agricultural viewpoint, the Delta Islands are a habitat for many forms of wildlife and are used extensively by hunters. The adjacent sloughs and rivers form an important fishery resource, and fishing, as well as other water-related activity, is an important attraction. The southwestern boundary of the site is adjacent to the State Game Management Area, and consequently the effect of the project on wildlife values in the areas will have to be carefully evaluated in any EIS. The archaeologic potential of the site is low. Control of

project water discharges to the adjacent river sytem will require careful study because of the adjacent wildlife areas and the importance of the fisheries resources of the Delta area.

The addition of the dredge spoil would reduce the danger of flooding by a simple increase in average elevation, since the island is presently entirely below MHHW. Deposition of the spoils would also probably result in a reduced rate of oxidation of peat deposits, with a consequent reduction in the rate of land subsidence.

Aesthetic considerations are primarily restricted to the visual impact of the operation on traffic along Route 160. The recreational potential of the Delta area is great and in any EIS it will be necessary to include a detailed consideration of the effect of the project on recreational values.

G. Fairfield - Dixon (Plate VI - 8) - In this area, the predominant feature is the rolling or flat agricultural land stretching from the hills west of Vacaville to the Yolo Bypass. There are many sites in this vicinity encompassing thousands of acres which would be suitable for land disposal. The farmland near Dixon and Davis is, however, more productive and thus more expensive, and the cost of development increases proportionately with the distance from the dredging sites.

One large site east of the Travis Air Force Base (Site No. 15) was chosen as being representative of the area. Development costs for sites farther north and east would be similar but would be increased in proportion to their distances from the dredging sites.

One other site, No. 14, near the town of Thomasson, between Cordelia and Suisun City, was chosen for study.

(1) Thomasson (Site No. 14)

Area: 4300 acres

Capacity: 69,000,000 cubic yards (10-foot depth - uncompacted)

This site is located at the extreme northwest edge of the Suisun Marsh and west of the Potrero Hills; it is presently used as grazing and agricultural land. It is above MHHW.

Solano County, in its Resource, Conservation and Open Space Plan shows the land to be of agricultural value but apparently imposes no other conditions on land use. The State Department of Fish and Game has proposed to include this site in an upland protection zone protecting the Suisun Marsh. ABAG has designated the site as controlled open space land. BCDC has no jurisdiction over the site.

Access to the site would have to be by pipeline paralleling Highway 21 since a pipeline traversing the marsh would probably be environmentally unacceptable. Operational effluent could be returned to the Bay via local waterways which also traverse the marsh.

The site has moderate wildlife use, and, as noted before, is adjacent to the Suisun Marsh. There is a significant potential for archaeologic remains. Potential for mudwave shallowing of adjacent marshlands is moderate. The proximity to valuable marshlands increases the potential negative consequences of accidental spillage of spoils or unprocessed runoff water.

(2) Travis AFB (Site No. 15)

Area: 8000 acres

Capacity: 129,000,000 cubic yards (10-foot depth – uncompacted)

This site is located on flat undeveloped hinterland immediately east of Travis Air Force Base. The site is typical of the area, which contains many potential sites. It is presently used for grazing and agricultural purposes.

The Solano County Resource, Conservation and Open Space Plan shows some agricultural and natural gas production potential but otherwise lists no

use constraints for the site. The ABAG Phase II Regional Open Space Plan designates the site as controlled open space. The site is not within BCDC jurisdiction.

Although the area is above the tidal range, it is generally quite low and subject to flooding. Most of the property drains toward the east to the Sacramento River via Lindsey Slough.

Two main high-tension power lines traverse the area between Travis AFB and Dozier,and a number of gas wells are located along the road east of Creed. An old railroad right-of-way traverses the area in a Northeast-Southwest direction.

Access to the site would have to be by pipeline, probably following the old railroad alignment from the Montezuma area. It is possible that the long distance pipeline transport mode could take advantage of a thickened slurry for economical pumping with a minimum of dewatering required thereby obviating problems of downstream contamination by run-off water. If not, however, it would be necessary to assess carefully the impact of injecting saline and possibly contaminated water at a point this high in the Sacramento delta. Salinities in this region are significantly lower than at other points lower in the delta, and the biological effects of a saline discharge could be considerable.

On the whole,the anticipated biologic effects of disposal at this site are expected to be moderate, particularly if discharge to the nearby slough is not required on a routine basis.

The proposed site has low to moderate wildlife use. There is some potential for archaeologic remains, although little direct evidence for them is available. The site includes areas which are potential sources for aggregate, which may have commerical value as a construction material. The effect of the operation on the possible economic recovery of this material should be investigated.

6.3 SITE DEVELOPMENT AND OPERATION

6.3.1 General - Before a land disposal site can be used for containment of dredged spoils, several preparatory activities must be accomplished. First, the site must be thoroughly studied by field reconnaissance, a review of available literature should be made, and in many cases a sampling and testing program of the surface and foundation soils should be conducted. As a result of this study program, factors which might affect the use of the site for disposal will be better known, such as the probability and estimated magnitude of settlements, possible failures of existing levees, weaknesses of surface soils which would preclude use of heavy equipment, etc. After this initial work, if there are no insurmountable problems evident, work may begin on site leveling, if required, other site preparation work, and dike construction. Provision must be made, of course, to protect or relocate existing utilities and facilities and to accommodate surface drainage which may be interrupted by the construction and operation of settling ponds. Distribution and drainage systems for operation of the ponds can be constructed concurrently with the dikes, and the site operated in accordance with predetermined criteria.

The following paragraphs outline development and operation processes for land disposal sites. General comments are offered on the evaluation of existing site conditions and on site preparation. Because of its importance in the Bay area, a separate section is included on foundation settlements. Another section contains dike design and construction considerations. Separation of the solids in a delivered slurry from the transporting waters is critical to the operation of a land disposal site; a section is included on separation by sedimentation and evaporation and examples are given of the design of primary and secondary ponds. A discussion follows on the placement of "processed" slurry, and a section is included in which representative sites are hypothetically developed and costs thereof are determined. Finally, the subjects of enhancement and future use of disposal sites are discussed.

6.3.2 Evaluation of Existing Conditions - The following paragraphs describe site conditions at three potential sites which are among the most promising of those identified, namely, Petaluma, Sherman/Jersey Islands, and Montezuma.

- Petaluma - This site (the most southerly of the sub-areas of Site No. 8, identified in Section 6.2) consists mostly of former marshlands which are presently used for farming and grazing. State Highway 37 crosses the southern portion of the property and a single line track of the Northwestern Pacific Railway parallels the highway on the south. Occasional dirt roads, most of which are private, traverse the site. A dredging company is located on the southernmost tip of the property near the Petaluma River Highway bridge.

The surface soils are desiccated and provide a relatively firm surface consisting primarily of silt and clay. The fertile zone is the old crest of the elevated parts of the bay mud and, according to a few test borings, it is approximately 5 to 6 feet in thickness. This overlies a soft, saturated gray clay, characteristic of the bay mud deposits which, as will be noted later, are very deep. Soil shear strengths vary from over 1500 pounds per square foot (psf) to 300 to 400 psf at a depth of 6 feet. The stiff soils underlying the bay mud consist of sands and gravels of moderate to high shear strengths.

The main levee along the margin of the property consists of dredged mud which appears to be relatively uncompacted; it varies in height from 5 to 15 feet. Most of the levees appear to be in satisfactory condition with irregular side slopes. At one or two locations, there are indications of some recent breaks, allowing small amounts of water into the site area. In these areas the older levees are overgrown with vegetation and have side slopes as steep as one horizontal to one vertical. Sloughing and erosion possibly created the steepened portions.

The elevation of most exterior levees ranges from 7 and 10 feet above sea level. Some parts of the interior levee system along the northernmost part of the property are as low as 2 feet above sea level. The old levees were

probably built by a drag line bucket excavating materials from the site.

Ponded water is present in many locations; field observations made during the winter season indicate this is a common condition. Most of the original sloughs present on the marshland are no longer in existence, having been filled 50 years or more ago during initial farming operations. Some drainage patterns and other indications of original sloughs are still present in the northernmost portion of the site. These are used for drainage canals with outlets along the Petaluma River through culverts placed underneath the exterior levees.

Most farming on the site is performed with lightweight bulldozers and cultivation equipment. The most common type of tractor used in the area is a Caterpillar D4 or equivalent size, generally with no blade or other attachments. A drag line was observed to be working northeast of the dredging company yard. Indications are that track-mounted equipment has little or no trouble working on the surface of the farmlands during wet or dry seasons. It is anticipated that the surface crust would be strong enough to support a D6C Caterpillar tractor or equivalent. When the surface of the desiccated mud is wet, it becomes slippery but is still passable with a track - type vehicle.

The desiccated crust of bay mud exhibits only low compressibility. However, the non-desiccated muds below are moderately to highly compressible and, as will be noted later, moderately high settlements can be expected under the weight of the dredged spoil, depending on its thickness and unit weight.

- <u>Sherman/Jersey Islands</u> - Most of Sherman Island (Site No. 13) is under cultivation. State Highway 160 traverses the island from northeast to southwest and connects with the Antioch Bridge. Pacific Gas & Electric Company transmission lines cross the island as do occasional dirt roads. Most of the dirt roads are inaccessible in the wet season due to the presence of surface water and poor road surface conditions. There is a paved road along most of the perimeter levee.

Numerous canals have been excavated to provide drainage of the low-lying areas. Most canals are emptied into the delta area over the levees by use

of either siphons or pumps. The large existing slough (Mayberry) on the west portion of the property no longer connects with the Sacramento River due to construction of an earth fill dam. In general, the surface conditions at Jersey Island are similar to the adjacent Sherman Island. Most of the island is under cultivation, but farming is not as extensive as on Sherman Island. The island contains numerous areas of subdivided land and canals, indicating that a considerable effort has been made at farming the reclaimed island. Jersey Island is surrounded by a levee, which is assumed to be in fair condition, since no obvious breaks or flooded areas are noticeable. The southern portion of the island appears to be higher than the remaining portions, which are as low as 10 feet below sea level. The areas of higher ground, according to published geological maps, consist of sand dunes which increase in areal extent to the south.

Both Sherman and Jersey Islands are typical of many reclaimed areas in the delta in that much of the property is below sea level. In general, the lowest interior elevation is about 10 feet below sea level, although the southern portion of Jersey Island is approximately 10 to 20 feet above sea level. The elevation of the levees varies from 10 to 18 feet above sea level.

Although the date of reclamation is unknown, it appears that the highlands were originally low-lying marshlands typical of the delta islands, which consist of slightly submerged or elevated bay lands containing considerable surface vegetation and occasionally sand dune deposits, particularly toward the south.

The surface of Sherman Island has been desiccated due to dewatering and farming. The crust of the soils varies from 2 to 5 feet in thickness. Soil conditions are rather heterogeneous, varying from pure peat areas to areas of silts and sands. Most of the peaty soils are in various states of decomposition and are interspersed with quantities of sand and silt. Beneath the peaty soils, there is usually found a layer of silt or clay a few feet to several feet thick which is in turn underlain by dense sands.

The soil strengths at the surface vary widely. In highly desiccated areas or areas with high silt or sand contents, the shear strengths are about 700 to 1000 psf. In areas where there is less desiccation, more decomposition, and less sand or silt, the shear strengths can be as low as 200 to 500 psf. When the soils are saturated, the strength will be even less.

The California Division of Highways found that the shear strengths of subsurface soils on Sherman Island decreased to as low as about 80 to 100 psf at a depth of 7 to 9 feet and then increased below that depth at a rate of about 10 psf per foot of depth to the bottom of the peat layer. Shear strengths in the silt and clay layer varied considerably but were usually higher than the shear strengths in the peat layer immediately adjacent. Shear stregths in the sands were moderate, with friction angles of 25 to 28 degrees and a cohesion of 300 to 500 psf.

The water level on the island is maintained at or below ground level by networks of irrigation and drainage ditches. The head of the water in the sand is higher than that in the peat which causes water to seep upward steadily through the peat which in turn requires pumping over the levee to keep the water level below the island floor. Because of the pumping, the water level is usually at the surface or only a few feet below. Water also seeps through the levees, especially in sections where they are built of sand or sandy materials.

Due to active farming, many farm vehicles are present on the island. The most common farm tractor is a Caterpillar D4 or equivalent size. Specially-designed double rubber-tired tractors were observed hauling cultivation equipment, particularly through the moist and wet fields. Other types of equipment observed were light-duty scrapers and miscellaneous farming equipment. At the present time, most areas of Sherman Island will support light tractors and scrapers; however, it has been found that repeated traffic on the surface of the peaty subsoil will cause its strength to rapidly deteriorate. This would be especially true in areas where the strength is initially low and when the soil is saturated, such as it will be when a slurry fill has been placed on it.

● Montezuma - Montezuma disposal site, identified as Site No. 12 in Section 6.2, is generally level and increases slightly in elevation toward the east. Construction of an exterior levee adjacent to Montezuma Slough reclaimed the site area from marshland. At the present time only a small amount of the site, principally in the south portion of the area, is used for farming with the remaining portions being used for cattle and sheep grazing.

The exterior levee adjacent to Montezuma Slough is in moderately good condition. Most of the levee appears to consist of dredged material dumped on the site during levee construction without the use of compaction or slope grading equipment. Most of the levee is overgrown at the present time and slopes appear to be ragged and irregular. Smaller interior levees are present in the north half of the property. Man-made drainage canals are present throughout the property; there is no apparent evidence of ancient sloughs which may have existed prior to reclamation. Maximum elevation on the exterior levee is about 8 feet below sea level, with the average approximately 2 to 3 feet below sea level. Most canals are drained into the slough by siphons or pumps.

The numerous canals which have been cut across most of the northern half of the property appear to be shallow and ineffective for draining the large amounts of standing water. Accessibility to the site is poor. The existing dirt roads are partially submerged and access by wheeled vehicles is limited to dry periods and periods of low water level. No equipment was observed to be working on the site during the reconnaissance.

There is no indication of the presence of ancient sloughs which may have existed in the original marshland. Most of the area has been regraded for farming and old sloughs have been filled.

The surface soils consist of peaty clays and silts which are generally soft and saturated. In the areas to the north where little or no cultivation is apparent, the surface is covered with water and natural marshland vegetation is present.

The subsurface soils are similar to those on Sherman Island, consisting of peat, silts and sands. Shear strengths and compressibility of the materials are essentially the same as those of the Sherman Island site. It appears that the Montezuma disposal site would require extensive preparation prior to any disposal operations. The southern part of the site consists of generally soft and saturated soils and the northern part is actually underlain by water with marshland deposits. It would appear that only very light farm tractors would be able to traverse the southern portion of the site during drier periods. It is doubtful whether light tractors could be used extensively on the northern portion of the site until a layer of fill had been placed.

6.3.3 Site Preparation - Site preparation involves site leveling and other work required preparatory to fill placement. In the following paragraphs, general considerations pertinent to site preparation are discussed. As an illustration, the estimated required site preparation work at the three sites evaluated in the previous section is outlined.

Site leveling to assure uniformity of slurry thickness may require the filling of existing sloughs and drainage canals within the disposal area if it is determined that these existing channels will not be used for drainage purposes. It is desirable to fill in the canals to provide an even thickness of slurry fill and an even surface for the equipment to work on. This will also help to prevent differential settlement which may be important in terms of ultimate site use.

Additional site leveling can be accomplished by adding fill material in the low spots or, less desirably, cutting the high spots. Cutting existing material could disturb and weaken the existing surface materials.

It is essential to have surface materials that provide a good crust as a working pad for the equipment during initial development of the slurry pond. If the crust is of insufficient strength or wearability, the equipment will sink through to the softer underlying soils, causing reduced mobility. The competence of this crust helps determine what type and size of conventional and special processing equipment can be used.

An existing weak surface crust can be improved by importing fill material and compacting it to form a good working surface. The imported fill could be dredged spoils that have already undergone processing.

- Petaluma Site - In order to prepare this site for acceptance of slurry fill, relatively little work will be required. The site is already fairly level, but site preparation should include leveling the pond areas to allow a fairly uniform thickness of slurry fill. Leveling should be done in such a way as to minimize disturbance of the existing crust. This can be done by filling the low areas with imported fill or processed slurry from other areas. If the fill is not to be processed, then the leveling is not so important, unless differential settlement will affect ultimate site use.

Stripping of vegetation will not be required as long as the pond areas contain small grasses. If large bushes or areas of heavy vegetation are present, they should be removed, with care being taken to minimize the disturbance of the surface crust. The existing surface crust is estimated to be five to six feet thick, which should provide an adequate working surface. When final pond locations are chosen, they should be inspected for localized soft or weak spots and upgraded as required.

The exterior dikes in the southern portion of the site will need to be repaired. A stability analysis will be required to determine the dike configuration. Repair work should be made with impervious soils that can be either processed slurry or imported fill. These soils should be compacted to 85 percent relative compaction with track-laying equipment.

- Sherman/Jersey Islands - Site preparation for these islands will be about the same because of the similarity of the conditions on the two islands. Both islands in general are level, except Jersey Island has some high sand dunes in the southern portion. Leveling will be required at both sites.

In selecting a source of material for leveling or crust enhancement, the sands of these islands should be avoided. Studies have indicated that a saturated sand blanket placed under slurry fill has not been satisfactory as a working

pad. Tracked equipment has a tendency to mix the sand in with the slurry, thereby deteriorating the working pad.

The stripping of surface vegetation will not be required in areas of marsh grasses or low plants. However, any larger vegetation should be removed.

The existing crust on both islands appears to be fairly competent in areas of cultivation due to the desiccated surface soils. In areas where no cultivation has taken place, existing surface soils generally are weaker. The peaty soils are easily deteriorated by equipment, especially when in a saturated state.

To upgrade the existing surface crust, it may be necessary to rework the surface soils by drying them to near optimum moisture content and compacting them. However, the underlying soft soils may not be able to support working equipment. An alternative would be to place and compact imported fill over the soft surface to form a stiff working surface. This material could be processed slurry from other sections of the property or from adjacent disposal sites. Compacted fill roads should be constructed in areas of high traffic.

The conditions of the exterior dikes on Jersey Island are unknown but are expected to be similar to those of Sherman Island, which are generally good. Repairs on these levees will be required in localized areas of erosion. Where the side slopes are very steep, stability analysis will determine if upgrading will be required. The criteria for repair should be the same as those for the Petaluma Creek site.

- Montezuma Site - Special site preparation will be required for most of this site due to the soft saturated surface soils. These soils, consisting mainly of peaty materials, will have to be handled in the same manner as discussed in the section covering Sherman and Jersey Islands.

The exterior levees appear to be in moderately good condition and required repairs would be limited to localized erosion zones, unless stability analysis shows the levee side slopes to be too steep. Repairs should be in accordance with the criteria discussed for the Petaluma Creek site.

6.3.4 Settlement - Most of the area adjacent to the San Francisco Bay is underlain by varying thicknesses of the ubiquitous "bay mud." In the Delta region, another prevalent foundation problem is that of thick peat layers which underlie the surface soils. Since most of the potential sites studied have foundations of either bay mud or peat, it can be expected that there will be settlements of varying amounts at most sites due to the deposition of the dredged fill. An estimate of anticipated settlement is essential for proper design.

The settlement estimates in the following paragraphs are based on the assumption that consolidation only will occur and that there will be no subsidence due to lateral displacement of the mud. If filling rates do not exceed 3 feet per year and no lifts greater than about one foot are placed during one operation, there should be little danger of lateral displacement and the resulting formation of mud waves. The load-carrying capacity of the bay mud depends to a great extent upon the rate of loading. With slow loading in moderately thin layers, the foundation at any of the sites should be able to support the proposed load without difficulty.

Descriptions of foundation materials and estimates of settlements at representative locations in the study area follow:

- South Bay - The South Bay sites are underlain by bay mud of varying thicknesses. For example, at Bair Island, the thickness of bay mud varies from about 65 feet near the Bay to approximately 35 feet inland (Ref. 38). The average is probably about 40 feet. Average settlement with a 10-foot layer of dredged fill would be about 4 feet.

The site near the City of Fremont is underlain partly by bay mud in the northwestern area, and partly by unconsolidated alluvial sediments. The area is bounded on the southwest by an outcrop of Franciscan formation rocks which form the Coyote Hills. Depth of bay mud probably reaches a maximum of about 20 feet in the vicinity of Coyote Hills Slough (Ref. 48); settlement from 10 feet of fill in this area can be expected to be a maximum of 2.5 feet.

• North Bay - The potential sites in the North Bay area are underlain by some of the deepest deposits of bay mud. For instance, at the Petaluma site, records indicate that the depth of bay mud is greater than at any of the other locations considered in this study (Ref.48). It probably averages about 80 feet. It is estimated that ultimate settlement under 10 feet of compacted fill would be slightly over 6 feet. Of this, about 20 percent would take place during the first 10 years after placement, and it would take 80 years for 50 percent of the total consolidation to occur.

At Skaggs Island, available data indicate that the depth of recent bay mud deposits averages 60 feet. Ultimate settlements under 10 feet of fill should be about 5 feet. Approximately 25 years would be required for 50 percent of the consolidation to be completed.

Bay mud in the vicinity of Hamilton AFB is approximately 60 feet thick (Ref. 48). Ultimate settlements should be approximately 5 feet for a 10-foot fill. Approximately 35 percent of the expected consolidation would take place within 10 years, and about 25 years would be required for 50 percent consolidation to occur.

• Suisun Bay and Delta - As the San Joaquin - Sacramento Delta is approached from the west, a change in soil conditions is evidenced. At the Montezuma Site, foundation materials on the east side of the slough consist of mud and possibly some peat. Farther east, these Recent basin deposits grade into lenticular stream deposits of sand, silt, gravel and clay. Depth of the mud on the east side of the Montezuma slough is estimated to be about 10 feet. Settlement in this area would range from essentially zero at the extreme eastern side of the disposal area to about 2 feet adjacent to the slough.

Sherman and Jersey Islands are composed of highly compressible peat to a depth assumed to reach a maximum of approximately 30 feet (Refs. 60 and 61).

Previous experience with dike construction in the Delta indicates that without adopting special procedures it is difficult to prevent non-uniform settlement and associated cracking, although slow construction of the retaining dikes would probably minimize detrimental effects. Consolidation will also allow the shear strength of the peat foundation to increase before the next increment of loading is applied. The successful construction of a 21-foot high road fill on a peat foundation at placement rate of about 2 feet per week was reported by Weber (Ref.59). In this case, the fill was placed over sand drains. In another section of the same project, without sand drains, failure occurred when the fill reached a height of 8 feet. The sand drains apparently increased the stability of the foundation and allowed placement at this accelerated rate of construction, but Weber attributes the increase in stability to a pile action by the sand drains rather than a reduction in drainage path. Previous laboratory tests described in the same report indicated that the rate of consolidation is independent of sample thickness or length of drainage path. With the carefully controlled slow rate of construction recommended in this study, it should be possible to successfully raise dikes to the necessary heights without using sand drains.

Ultimate consolidation of the 30-foot layer of peat under a 10-foot high layer of compacted material with a unit weight of 90 pounds per cubic foot would be approximately 10 feet. If the thickness of the layer of fill were increased to 25 feet, the estimated settlement would be about 20 feet.

The peat soils will not only settle large amounts during the time when fill is being placed on them, but will continue to settle over a long period of time thereafter. Primary settlement will take place in a few months and be 30 to 50 percent of the total settlement. Existing levees are settling at rates up to six inches per year.

- Travis AFB Area - From the standpoint of foundation conditions, one of the best of the potential sites studied is the Travis AFB site (No. 15). This site is mainly on recent alluvial fan deposits composed of heterogeneous sediments ranging from clays to gravels. A few outcrops of non-marine sedimentary rocks, such as sandstone, claystone, and con-

glomerate, can be observed in the area. Bearing capacity of these sediments is much greater than that of the bay mud. Approximate estimates of allowable bearing capacity are between 2,000 and 4,000 pounds per square foot for the foundation in the Travis area compared with about 1500 psf for compacted bay mud fills. Sufficient materials from within the disposal area should be available for starter dike construction.

At all sites where settlement of any magnitude occurs, there will be an increase in the capacity for containing dredge spoil because of the settlement. However, where the potential disposal areas are protected from flooding by existing levees, these levees must be continually inspected during the pond filling process to detect any signs of distress, and provision must be made for maintaining adequate freeboard by increasing the crest height of the dikes as required.

6.3.5 Dikes

- General - Prior to placement of the dredged spoils, it will be necessary to design and construct a system of dikes which will form ponds of the required configurations. In addition, existing peripheral dikes will probably have to be strengthened and repaired, or possibly rebuilt.

Many of the retaining dikes constructed for containment of dredged material in the past have been constructed without regard to good engineering practices; they were often constructed in areas with questionable foundations by draglining or bulldozing material from the borrow area in a loose state with no attempt at compaction. In the WES report (Ref. 52) mention is made of many cases of dike failure due to poor foundation conditions, poor construction materials, minimal inspection during the dredging operations, and uncontrolled seepage.

In most locations where dredge spoil containment dikes are built, there would probably be little danger to life and property in the event of a failure. However, significant costs may be incurred in replacing material

lost due to the break, in addition to dike rebuilding costs. Of greater importance, would be the adverse effects of the release of turbid water and polluted sediments into adjacent waters.

- Specific Recommendations for Design and Construction of Dikes - For the preceding reasons, it is strongly recommended that dikes be designed and constructed in accordance with sound engineering practices to ensure their safety and stability during all phases of construction and operation. This would significantly reduce the likelihood of a dike failure with its consequent unfavorable reflection on the dredging agency.

The Corps of Engineers (Ref. 51) recommends that the following criteria, adapted from EM 1110-2-2300 (Ref. 63), be followed in the design of dikes:

a. The slopes of the dike must be stable under all conditions of construction and operation.

b. The dike must be designed so as not to impose excessive stresses upon the foundation.

c. The passage of seepage flow through the dike and foundation must be controlled so that piping, sloughing, and removal of material by solution do not occur. In addition, highly contaminated dredge spoil will probably require a limitation on the quantity of seepage flow and groundwater contamination.

d. The freeboard must be great enough so that there can be no overtopping by waves. This requires also that the settlement of the foundation and embankment be estimated and provided for.

In the Bay area, which is close to several active faults, seismic considerations must be emphasized during design to assure a stable structure under earthquake loading.

Retention dikes would impose the most concentrated load on the foundation. To assure that the dikes do not overload the foundation and that they will be stable under earthquake conditions, they should be built in

stages as needed over the life of the project. Substantial savings will result if the filling of the ponds is slow enough to permit staged construction - this will allow the foundation soils to consolidate and allow steeper slopes to be built. Even with staged construction, it is recommended that the dikes have slopes not steeper than 3 horizontal to 1 vertical and preferably not steeper than 4:1.

The dikes could possibly be constructed of fill from site excavation, compacted dredged material, or selected fill. If the dikes are built of material from within the disposal area, precautions should be excercised to preclude cutting the crust of the foundation too thin. Normally this crust of dried mud has formed in areas above high tide but soft mud still exists below the cover. A typical example of this phenomenon exists at the Petaluma River site, where the Soil Conservation Service (Ref. 37) estimated that the crust thickness varies between 3 and 8 feet, and that the lower boundary of the crust is an undulating surface.

No excavation within the disposal area should be performed until the thickness of the crust has been determined so that adequate precautions can be taken to prevent the crust from being cut too thin to support equipment. Initial dike construction and all subsequent dike raising should be to the minimum height required to retain the material from the particular cycle of deposition. In addition, construction should be performed only during the dry season when the surface crust thickness is at a maximum.

Dike construction material should be impervious soil, compacted to approximately 85 percent relative compaction. (as determined by ASTM D 1557-70 (C) laboratory test procedure).

Dried dredge spoil, if properly compacted, will be suitable for construction of subsequent lifts to the dikes. Bay mud was successfully used for construction of dikes at the Redwood Shores development, which is discussed in a later section.

Most of the existing dikes observed in the field will require improvement, as their present slopes are generally much steeper than 4:1, and no reliable information is available on the materials used. In addition some reports indicate that normal construction was with draglines or clamshells, with no spreading or compaction of the dumped materials.

Differential settlement of the dikes due to pronounced irregularities in the foundation materials would only become critical in those areas where severe cracking and large deformation resulted. Generally, such irregularities will exist in the vicinity of sloughs where abrupt changes in the thickness of bay mud are found. Special design and construction methods in these locations will be required to prevent dike failures and repeated maintenance expenditures.

6.3.6 Separation of Solids from Transporting Waters

A. General - It is conceivable that dredged materials could be distributed at the land disposal site in a substantially solid form; for instance, a scow filled with clamshell excavated spoils could be unloaded into a truck or conveyor distribution system at the site. Because of the technical problems and rehandling costs involved with such a system, however, sediments dredged from the waters of the San Francisco Bay-Delta system and moved to land disposal sites will, very probably, be transported in a slurry form by pipeline. The pipeline could lead from a dredge in the vicinity of the disposal site; it could be a fixed pipeline from a distant location; or it could lead from a rehandling basin at the site itself. In any case, substantial benefits of placement of spoils by the hydraulic fill method can be realized if the solids transported can be concentrated at the landfill site and if appropriate means are found for disposal of the transporting waters.

Examination of the feasibility of hydraulic fill methods for land disposal requires an investigation of the physical properties of the spoil, the character of the transporting waters, and the character of the deposited material. Even with this information, feasibility can only be evaluated for specified separation processes. This section presents, therefore, data on the sediments and waters to be disposed together with an outline of recom-

mended separation facilities. Considerations concerning facility design and an estimate of facility performance are included.

B. Spoil Material Properties - Sediments enter the San Francisco Bay-Delta system from land drainage and consist largely of erosion products from the land surface. About 81 percent of the material enters with Central Valley drainage, and most sediment from all sources enters during the winter and early spring months with higher rainfall runoff and snowmelt water flows.

The entering sediment materials are comprised of about 60 percent clay sizes, 30 percent silt sizes, and 10 percent or less fine sand. This fine material is transported largely in suspension in the entering streams. The very small clay and silt particles become cohesive when ocean waters mix with river waters to the extent of one part or more ocean water to 33 parts fresh water, however, and the hydraulic conditions in the San Francisco estuary cause repeated particle collisions, which result in aggregation of suspended particles. The settling velocities of the aggregates are much greater than those of individual mineral particles. As the flow of entering water passes into the broad shallow bays of the system, the reduced water velocities and shallow depths facilitate deposition of suspended material.

During the late spring and summer months, daily onshore breezes blow across the shallow bays and generate waves that resuspend the recently deposited material and keep it in suspension; even the slow tidal currents circulate suspended material throughout the system. Finer materials are preferentially resuspended. When the wind dies or wherever flow velocities are small in deeper waters, such as in channels and harbors, deposition occurs. These processes continue and the sediment gradually works its way to regions where hydraulic shear stresses necessary to resuspend the material do not occur, or the sediment moves out through the Golden Gate. Because of the abundant supply of material to the system, averaging about 10 million cubic yards each year, areas where resuspension is limited must of necessity be dredged if depths in these areas are to be maintained.

The foregoing description of the transportation patterns shows that the material can be deposited and resuspended repeatedly.

For this study, representative locations in each shoal area were sampled and tested to determine the properties of each. A copy of the report, Core Samples of San Francisco Bay Sediments, dated December 1973 and prepared by CSO Laboratory, is included in Appendix A. This report shows the details of sampling, including locations at which core samples were taken in the various shoals, and apparent density and moisture contents of the soil samples. Data from this report are tabulated in Table VI-1.

The physical data show that the materials in the several shoaling areas differ significantly, with sandy areas, such as Pinole Shoal, having higher apparent densities and lower water contents than areas of softer clayey deposits.

Both chemical and physical tests were performed on the samples recovered through the sampling program. Settling tests and chemical tests will be described later in this Section; physical tests, performed by the Harding-Lawson Associates Laboratories, are described in Appendix C.

C. Settling Characteristics - Samples from each of the shoals were mechanically suspended in one-liter graduated cylinders at several concentrations and allowed to settle. The concentrations, selected to be such that hindered settling* occurred, were approximately 10, 20, 40 and 60 grams of solids per liter. The settling at various times was determined by observation of the sediment-water interface location on the graduated scale.

Aggregation** and hindered settling occurred when the samples were suspended in sea water. The material dispersed when suspended in tap water and did not settle.

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* Hindered settling occurs when a high concentration of solids settles to a boundary (bed) and, as the particles accumulate on the bed, the water displaced by them moves upward through the settling particles and reduces their apparent rate of settling.

** Aggregation is a collection of separate suspended particles into one unit, which behaves as one suspended particle.

A useful method for reducing such data was devised using Bosworth's relation (Ref.84):

$$\frac{V}{V_\infty} - 1 = \frac{k}{t},$$

where V is the volume at any time, t, V_∞ is the ultimate settled volume, and k is a time constant. Plots of V vs 1/t, of which Figure VI-1 is typical, showed linear portions in their later stages which could be extrapolated to the ordinate to yield the settled volume. The intercept volumes were plotted against weight of sediment as shown in Figure VI-2. The lower curve indicates the settled volume after approximately one day of settling. The linearity of the points in Figure VI-2 indicates that the structure of the deposit was the same for all initial concentrations tested.

The results of the settling test are presented in Table VI-2 together with the in-place shoal apparent densities and water contents. These data show that the densities of the shoal may be expected to be significantly higher than those of an initial deposit at a site. It appears that the particles in even a thin deposit slowly rearrange themselves to form a more dense deposit for weeks after deposition.

The concentration of particles in the fresh deposit are shown in the last column of Table VI-2.

The plots of V vs 1/t and intercept volumes vs sediment weight for all samples tested are included in Appendix D.

D. <u>Tentative Disposal Scheme</u> - The following facilities and operation are suggested for purposes of evaluating the feasibility of land disposal:

1. Facilities would include a number of diked primary ponds and a pair of parallel secondary ponds for storing and settling elutriate waters from the primary ponds. Valved lines would control discharge from the

spoil conduit to each of the several primary ponds, stop-log weirs would control effluent discharge from the primary ponds, and a canal with appropriate appurtenances would carry effluent to the secondary ponds. Effluent from the secondary ponds would be pumped to a submerged discharge leading to the adjacent slough, river, or bay.

2. The primary ponds would be operated successively on a batch basis. The batch procedure would include:

a. Filling the pond until sufficient sediment to make the desired depth of deposit was admitted.

b. After settling for a desired period, skimming the supernatant water by means of the stop-log weir and allowing further drainage as consolidation progressed.

c. Leaving the deposit exposed to sunlight and wind until the moisture content of maximum shrinkage was reached. Drying might be accelerated by mechanical thickening during early stages and scarification during later stages.

3. The secondary ponds would be provided in pairs to allow for maintenance and to provide storage capacity for accidents or for river conditions such that discharge is permitted during only a portion of the tidal cycle.

The several factors affecting the conceptual design needed for evaluation of feasibility of such facilities are described below:

E. Influent Slurry - In the absence of other information on dredging schedules, the production of slurry was assumed to be distributed uniformly over 365 days each year. The production for a design year during which dredging was taking place at all dredging sites was taken as 14,694,000 cubic yards; the 20-year total was taken as approximately 200,000,000 cubic yards. Shoal volumes dredged daily were taken to be 40,258 cu yds and 27,000 cu yds, respectively.

The solids concentration will probably vary with the character of the shoal material, the kind of dredging equipment used, and the individual operators of the dredging equipment. High solids concentrations approaching those in the shoal will facilitate drying but will require spreading facilities at the disposal site. Low concentrations can be distributed easily at the landfill site but may require longer periods for draining and drying, and therefore will encumber larger land areas for drying.

Inevitable fluctuations in solids concentrations will require facilities for concentrating solids and separating them from the transporting waters. A bulk density of 1150 g/l or a solids concentration of 0.204 g/cu cm is expected to typify the influent slurry (Ref. 55) with periods having lower solids content, although solids contents up to 1200 g/l have been obtained in the Delaware Estuary with pilot scale experimental equipment dredging shoal material having slightly lower apparent densities than those in San Francisco Bay. Slurries having the lower solids concentrations pose the greatest problems for separation and drying solids, and are the primary concern in this study.

F. Primary Pond Requirements - The area required for primary ponds, their configuration, and their appurtenances are determined by climatic conditions as well as by the settling character of the material and facilities for operation. For purposes of the following example, climatic conditions at the Delta site of Sherman Island were used. Sherman Island is subject to daily westerly breezes during summer and to occasional north winds when high pressure areas cross the upper Sacramento Valley. Monthly evapotranspiration rates vary from near zero during winter months to about 9 inches per month in summer as measured near Thornton (Ref. 85). Consideration of the winds and the varying evaporation rates are included in the requirements in this section.

Shoal volumes, areas covered and water to be evaporated from a one-foot wet deposit, at both densities obtained after one day of settling and at shoal density, are presented in Table VI-3. Densities obtained after one day of settling and those of the shoal were selected because they show the range of achievable values. Shoal densities should be approached with one to two weeks of undisturbed settling. The top few centimeters of a consolidated deposit will have a lower density than that shown, but the average for one-foot should be approximately as indicated, based on measurements on core samples of the shoal. The lower portions of the one-day deposit should be slightly more consolidated than indicated by the settling tests, so that a deep deposit might have a higher density. The values in Table VI-3 provide limits to the range to be expected by varying the settling times.

Water to be evaporated to a moisture content of 30 percent by weight* is shown in the last two columns of Table VI-3, and weighted average areas and water to be evaporated are shown at the bottom. These weighted average values are used subsequently for estimating total area required for primary ponds.

A plot of cumulative evapotranspiration from a station in the Delta is presented in Figure VI-3. The curve shows that the average rate of 48 inches of water per year is exceeded from the end of March to the end of September, and evaporation rates are very low during the period October through February. In order to accommodate uniform year around disposal it will be necessary to provide exposure for long times for material not dried before the end of September.

The times required to evaporate several selected amounts of water were determined graphically for each 15 day period throughout the year using the plot in Figure VI-3 and a similar plot on a larger scale. The number of

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* Target moisture content recommended by Mr. Lyle Lewis, Harding, Lawson Associates.

15-day pond groups required was then determined by plotting the times that each group was occupied by filling, settling, and drying as shown in Figure VI-4.

Figure VI-4 was based on an 8 day filling and settling period added to the drying times determined graphically for evaporating 12.8 inches of water. The abscissa represents time of year and the ordinate lists number of pond groups occupied. The bars indicate the period during which each pond group is occupied and the letter indicates the order of occupation. Figure IV-4 shows that 15 pond groups would be needed for uniform year around spreading at depths that would require evaporation of 12.8 inches of water. It also shows that the ponds would be idle during summer months. Less total pond area would be required if the dredging schedule could be adjusted to match evapotranspiration rates.

The nonlinear character of the cumulative evapotranspiration curve makes the total number of pond groups required vary with amount of water evaporated. The exercise leading to Figure VI-4 was completed for four amounts of water to be evaporated and the total number of pond groups found were plotted as shown in Figure VI-5. The curve in Figure VI-5 tends to become horizontal with increasing depth of water because the winter month periods are less significant as the drying periods lengthened: At 48 inches of water all ponds would be occupied the entire year. The formation of a surface crust and drying rates at depth preclude this option. It appears possible, however, to spread the material thinly during winter months and thicker during summer months to keep the ponds occupied during a greater portion of the year. This mode of operation was not investigated. It may also be desirable to store material during winter months and spread during the "drying season."

Calculation of total area required using the weighted averages in Table VI-3 and the curve in Figure VI-5 proceeds as follows:

1. Select a desired depth of deposit and an appropriate density and calculate the daily area and total evaporation. For example, a 6-inch deposit having the shoal density would require 52/0.5 = 104 acres per day of spreading area. The water to be evaporated would be 5.92/2 = 2.96 inches.

2. Enter Figure VI-5 at 2.96 to get 8.2 fifteen day pond groups. The total area required would be 8.2 x 15 x 104 = 12,800 acres. A similar calculation for a 12 inch deposit at shoal density yields 11.3 x 15 x 52 = 8,800 acres.

It should be noted that the water content after one day of settling is 1.5 times that of the shoal. One or two weeks of settling is beneficial.

A pond configuration with a length to width ratio of about 5:1, with the inlet at one end and the exit at the other, is desirable to provide a longitudinal slope to the bed for drainage, and to permit continuous flow operation without short circuiting, should it become desirable. The pond area should be small enough to spread slurry more or less uniformly from the inlet end but otherwise large so as to minimize dike construction and maintenance. An area 1000 feet by 5000 feet would provide 115 acres (just over one day's spreading to a 6" depth), and would be about as large as could be easily spread with dilute slurry.

The height of the dikes should be maintained sufficiently above the dried bed surface so that each load has ample freeboard. If a conservative 1.10 g/cc slurry density is assumed for, say, Mare Island Strait sediment with a shoal density of 1.30 g/cc, then a total slurry depth required for one foot of deposit at shoal density would be 3.7 ft of slurry. This depth plus freeboard leads to approximately six-foot dikes. A slurry having a bulk density of 1150 g/l would require only 2.2 ft depth. It is important to maintain the solids concentration in the slurry within a range such that spreading is facilitated and such that excessive water depths are avoided.

The ponds could be contained by dikes made high enough to provide, say, the slurry and deposit capacity needed during the first few years only. Successive lifts could be made from dried spoil with the adjacent deposited spoil serving as ballast. The foundation problems can be minimized for interior dikes by maintaining similar depths of deposit on either side.

Drying rates observed for evapotranspiration were used in the estimates above. These evaporation rates are lower than pan evaporation as a rule and were selected to more nearly describe water loss from the soil. Actual moisture loss from drying Bay mud may be less, however, because a dry, relatively impermeable crust develops at the surface of a drying deposit and inhibits evaporation. Two ways to reduce this effect include spreading in thin deposits, and scarification of the surface by harrowing or discing. If the site is ultimately to be used for agriculture or horticulture, surface treatments that promote the development of open, permeable structure should be selected for enhancing drying rates.

A recent article (Ref. 86) described studies of "conditioning" slurry to enhance evaporation rates and showed evaporation rates from conditioned sediment that were ten times the pan evaporation rates. The supporting data are not convincing, however, and no information is given that shows enhancement of surface drainage resulting from "conditioning" or absorption of moisture by underlying soil. Both can be useful, but until more definitive data are available it would be prudent to anticipate that scarification or shearing the material will be needed to <u>just attain</u> pan evaporation rates from thick deposits. Care should be taken to assure surface drainage from the deposit in any case.

The simplest approach is to spread to form a thin deposit. It may be difficult to spread a uniform layer the first few years, but the bed surface should soon stabilize. An upper limit to sediment depth of one foot of wet deposit appears appropriate to limit the height of containing dikes needed and to facilitate access to the interior of the ponds by earthmoving equipment.* Winds generate waves having greater height with length of fetch (over short distances). Orientation of the ponds to minimize the effects of winds is desirable. Placement of the long axis north to south will present the narrow dimension to the wind,and placing the inlet on the south end and the outlet on the north end will minimize disturbance by the north winds around the outlet. The ponds should be drained at a time when the air is calm so as to avoid suspension of bed surface material in the supernatant waters. Such conditions often prevail during early morning hours in the Delta.

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* Suggested by Sterling K. Atkinson, Harding, Lawson Associates, San Rafael, Personal Communication.

The settling tests showed that the shoal material disperses in tap water. Settling and consolidation in the primary ponds require that the particles be cohesive. Cohesion is assured when the sea salt concentration in the transporting waters exceeds a few grams per liter, as it normally does in most of the Bay system below Pittsburg except during periods of high fresh water inflow. If spoil is barged to the disposal site and pumped to the ponds using fresh river waters, however, it will be necessary to add coagulant. The most appropriate coagulant depends on cost: alum, ferrous salts, lime, and commercial polyelectrolytes should be investigated after laboratory measurements of the amounts of each prospective coagulant needed to assure cohesion are determined.

Before final design of primary ponds is undertaken, several additional efforts are needed. These include:

1. Additional settling and consolidation tests to determine and optimum consolidation time and to determine the effect of depth of deposit on water contents;

2. Drying studies to show the rate of drying for deposits having varying thicknesses during the entire drying period;

3. Studies of the benefits and costsof various scarification or consolidation methods; and

4. Refined operational studies, using the above information and knowledge of uses of dredging equipment in other areas during winter, that can lead to reduced drying area and construction requirements.

If may be possible to utilize existing land disposal activities for obtaining some of the information needed to optimize land disposal operations.

G. <u>Secondary Ponds</u> - Treatment of the supernatant waters drained from the primary ponds is necessary primarily to remove solids suspended during primary pond drainage and to provide a buffer against leakage of turbid waters.

Turbid waters are themselves objectionable if the turbidity exceeds that of the receiving waters, and deleterious substances, if they should occur, are often associated with suspended particles. Secondary ponds are suggested for continuous flow operation. Batch operation may be desirable at times, and the ponds should be equipped for such operation.

The following factors are important to secondary pond dimensions:

1. The water depth should be four feet or more for continuous flow operation to avoid suspension of deposited material by wind-generated waves. An extra two feet capacity may be needed for storage during unfavorable water conditions.

2. The length to width ratio should be 5:1 or more to reduce short-circuiting from the inflow to the effluent structure.

3. The effluent weir or pump intake should be floating or adjustable so that water is removed from near the surface, and so that batch operation is possible.

4. The size was determined for continuous flow assuming a maximum supernatant production on a desired one-foot of deposit in the primary pond settled from the slurry having an apparent density of 1.100 g/cc, described above. The supernatant would have a volume of 52 acres by 2.67 feet or 138 acre feet per day. The flow would be split and pass through two ponds, each selected by trial to be 400 feet by 2000 feet by 4 feet deep. The characteristics of these ponds during the maximum flows are:

Surface Loading	4.4×10^{-5} ft/sec
Average flow velocity	.022 ft/sec
Detention time	25 hours

The low velocity assures that bed shear will be negligible so that deposited material will not suspended by the flow. The surface loading is an estimate of the minimum particle settling velocity for particles that will be entirely removed by the pond. Laboratory studies indicated that median settling ve-

locities for Mare Island Strait sediments, after having reached later stages of aggregation, had this settling velocity when the suspended solids concentration was 210 mg/l. Effluent suspended solids concentrations for higher influent concentrations should be low. The portion of solids removed at lower influent concentrations will not be as great, however. Effluent concentrations should not exceed 50 mg/l in any case.

These secondary ponds will store at a four-foot water depth an entire day's supernatant production so that it would be possible to operate them on a batch basis should that become desirable.

H. Other Treatment Requirements - Investigations of additional requirements for treating supernatant waters included analyses of elutriates of the shoal samples obtained by shaking one part sediment with four parts water, by weight, for 30 minutes, then settling the solids and filtering the supernatant. The elutriates obtained by shaking sediments with sea water and with tap water, to simulate river water, were analyzed for cadmium,mercury, lead, zinc, immediate dissolved oxygen demand (IDOD), biochemical oxygen demand over five days (BOD_5), total phosphorus, total nitrogen, and nitrate nitrogen. The results of these analyses, made by Environmental Quality Analysts, San Francisco, are included in Appendix B.

The analyses show that the concentrations of cadmium, lead,and zinc in both the tap water and seawater elutriates are well below permissible levels listed in Surface Water Criteria for Public Water Supplies (Ref. 94).

Mercury is not listed in the tabulation. Mercury has a molecular weight 1.8 times that of cadmium. If their toxicities are comparable, then the permissible concentration by weight should be about twice that of cadmium. Examination of the data show mercury concentrations less than two tenths of the permissible level,with one exception. The exception is the mercury in the elutriate from one of the samples from Redwood City Harbor. It is ten times that for the other Redwood City sample and no comparable change is apparent in the other metals for the sample. It appears that there was an error in calculation. The metals should not be a problem to receiving waters at the west end of the Delta or in the Bay.

The IDOD values probably reflect oxidation of ferrous sulfide contained in anaerobic sediments. The values are low, and would be satisfied rapidly in the large exposed ponds. The BOD_5 values show surprising differences in tap water and seawater elutriates, with the seawater elutriate BOD_5 averaging about 111 mg/l and the tapwater elutriate averaging 48 mg/l.

Oswald (Ref. 87) presented a table which shows BOD_5 reduction at various times and temperatures in undisturbed ponds. At nine days, the reduction is 57 percent at 10° C and 75 percent at 14° C. At the lower temperature, the effluent concentration would be 37 mg/l if the proposed ponds perform in comparable fashion.

The primary ponds will have shallow supernatant depths relative to conventional pond depths, so that aeration by surface mixing and diffusion should be more efficient than that in conventional ponds. It is suggested that facilities for aeration be omitted at the present stage of planning, but that the slurry be settled eight days in the primary ponds before the supernatant is drawn off.

The nitrate nitrogen concentrations in the tapwater elutriate are slightly above those in Suisun Bay and the western Delta (Ref. 88) and the phosphorus concentrations are about three times those found in these waters. The phosphorus concentrations in the seawater elutriates are comparable to those in the receiving water, however. It is not anticipated that either nitrogen or phosphorus will be of concern for the quantity of water discharge anticipated.

Analyses of organohalogens, shown in the EQA report, showed virtually no pesticides or residues released in tap water. Only three observations of pesticides at barely detectable levels were noted in the seawater elutriates, and only up to three times the detection limits were observed for polychlorobiphenyls. The one DDT value detected is at one-sixth the 48 hour TLm for shrimp (FWPCA Water Quality Criteria, page 83). This sample came from Napa River, a shoal area that will contribute only a small part of the total sediment. No criteria are available for PCB's. It is not anticipated that pesticides will be a problem.

The remaining constituents in those supernatant waters that are pumped up from the Bay to the disposal areas are the sea salts.

The waters of the Delta are used by local farmers for irrigation water supply and for waste disposal (irrigation return flow), by the Department of Water Resources of the State of California (DWR) and by the Bureau of Reclamation (USBR) for irrigation and domestic use, and the waters downstream are used by industries and by cities such as Antioch. The salinities of water in this region are monitored by the DWR and USBR and are reported to the California Water Resources Control Board as required by Decision 1379, issued by the CWRCB in July 1971. The amount of water that can be exported by pumping near Tracy is limited at present during low fresh water flows by the intrusion of sea water up the estuary.

Approval for discharge of saline waters would require model studies to determine the effect of the discharge on Delta waters, and evaluation of these effects by appropriate agencies. The effects may be small, and the value of reclaiming an island is high. The possibility of approval should not be discounted.

The effect of the discharge of saline waters from the settling ponds would not be a problem downstream of Suisun Bay. If sites are considered upstream of this location and policies are such that the effluent cannot be discharged into the adjacent waters, the evident alternatives are (1) to return the saline waters to the Bay through a parallel pipeline or through the influent pipeline during "down" times, if storage is adequate in the disposal areas to allow the pumping to be shut down, and (2) to transport the dredged material in scows or barges and then place it hydraulically in the disposal areas with local water. In this latter case, it would undoubtedly be necessary to use coagulants to precipitate the solids.

1. Conclusions - The foregoing study has indicated several aspects of land disposal of dredged material that bear on the feasibility of such practices. The most important of these aspects are:

1. Transporting dredged spoil as a slurry in pipelines and placing the material hydraulically is physically possible if the particles are mutually cohesive. Either sea salts or a coagulant will make the particles cohesive.

2. It is desirable to place the material in thin layers to obtain more uniform drying and to provide access by earthmoving equipment. Less than one-foot (wet) and preferably 6 inches appears to be the most desirable thickness.

3. Careful control of the water content of the slurry will:

a. Minimize the height of dikes needed,
b. Minimize the supernatant waters to be treated and discharged, and
c. Allow easy spreading of material over large areas

4. The primary ponds should be filled and allowed to stand without draining for approximately a week to facilitate reduction of BOD in the supernatant water, to allow consolidation of the deposit, and to remove suspended solids from the supernatant waters.

5. Secondary ponds are desirable to provide protection of the receiving waters from disturbed deposits during primary pond draining and inadvertant suspension. Secondary ponds would also provide short term storage when discharge on ebb tide only is desired.

8. The primary pond area is largely determined by the need for winter storage in year-around operation. The feasibility of using land disposal only during the months affording high drying rates (April through September) should be investigated to reduce the required area.

7. "Conditioning" spoil to accelerate drying should be appropriate to future intended uses. Agricultural soil material should not be compacted. Mechanical "thickening" with rakes or other equipment to release water and promote densification during the first day or two of exposure of the wet deposit should be investigated.

8. Final design of spreading facilities should be prceded by additional measurements on the settling and drying characteristics of the spoil, model studies of effluent salt distribution in Delta waters, if it is planned to locate the disposal area in the Delta, and consultation with appropriate agencies.

6.3.7 Slurry Processing

A. General - The ultimate planned use of a land disposal site will dictate the required amount of processing of the settled material. If development requiring densely compacted fill is not planned, or is not desirable, as in the case of agricultural lands, the slurry may be spread hydraulically and not processed except for drying and possibly scarifying, as described in the preceding section.

The density of dredged material is altered during the transporting and placing process. The volume increase during the transport phase is extremely variable, ranging from as high as a 500 percent increase where a hydraulic dredge is used to as low as 10 percent as estimated for hopper dredges. In a few days after placement in a disposal area, after the water has been decanted off, and a film has started to form on the slurry, the volume is about 1.5 times the shoal volume. The plot on Exhibit C-11 in Appendix C illustrates the approximate moisture/volume relationships in the laboratory for five of the samples from shoal condition to an oven-dry condition. For a final water content of about 30 to 40 percent, the reduction in volume is from 45 to 50 percent. However, it should be noted that for actual conditions in the field where the moisture content is an average of 30 to 40 percent, the moisture content will vary from near zero at the surface to possibly 60 to 80 percent or more at the bottom of the layer. In the field there will also be significant cracking at the surface. Therefore, the actual volume in the field would be more than indicated on Exhibit C-11. The top to bottom moisture contents become more widely separated as the lift thickness increases.

Also presented on Exhibit C-11 is a comparison of compacted volumes of Sample 9 to the volumes of Samples 3, 7 and 12. As is evident, an additional decrease in volume of from 5 to 15 percent or more, when compared to air dry conditions, can be achieved by compaction. In general, it can be said that a volumetric decrease of 2:1 can be obtained if the material is dried and compacted in the disposal area - that is, the volume in the disposal site would be 50 % of that in the shoal.

In the case where the slurry is to be spread hydraulically with no processing, no special preparation such as site leveling or treatment of the surface of the area is required unless future differential settlement will be a problem.

In another case, the future planned use of a land disposal site may be such that it is desirable to place imported fill material on top of the unprocessed slurry to allow it to support light to moderate loads. In this instance, adequate drying time will be necessary to allow the surface crust of the slurry to develop sufficient strength to prevent overstressing by the new fill. Drying time will vary, depending upon how thick the slurry fill is and how much imported fill is to be placed.

In all cases, it will be necessary to place a 12- to 24-inch working pad of uncompacted fill material over the surface crust of the slurry. As the working pad is being pushed across the pond, additional fill can be compacted in place behind it.

This additional fill will cause increased consolidation and settlement of the slurry fill and the underlying soils, which should be taken into consideration in the site planning process.

B. Processing - It may be desirable or necessary, because of the future planned use of the site, to process or "condition" the slurry fill. As noted before, the compacted spoils will have a volume of approximately one half that of the bank run volume, which increases site capacity. The end product of processing can be material compacted in place to form an

engineered fill or used in other areas as an imported fill material. The compacted dredged spoils have maximum dry densities varying between 95 and 116 pounds per cubic foot (pcf) (using testing method ASTM D 1557-70 (c)) and a shear strength of about 1550 psf.

Since the conditioned material has reasonably good structural qualities, it could possibly be in demand in areas where fill is at a premium. However, as will be noted later, the processing costs are quite high, so processing should not be considered unless an apparent need exists for the conditioned material. If time is available, processing costs may be reduced if the material is placed in thin lifts and allowed to dry to the optimum moisture content before compacting equipment is used.

As noted earlier, the size of the primary pond is a function of the quantity of material received, the intake rate, and the desired thickness of the slurry fill. A high quantity of fill would obviously require a greater area than a low quantity. Also, a high intake rate may require using more than one pond at a time. The thickness of the material in the pond can determine how quickly the material can be processed and the pond made ready for reuse. The frequency with which a site would be used will also affect the operation. A high frequency use may require very rapid processing techniques, where a low frequency use may not.

In Section 6.3.6, it was noted that the best results in dewatering slurry ponds are obtained by spreading the slurry in thin lifts - the suggested maximum thickness is 12 inches. Slurry can, however, be placed in any desired thickness. The ultimate site use, the desired processing time, use of the processed material, and the processing equipment should all be considered in selecting the slurry thickness. The evaporation rate at the disposal area and the characteristics of the slurry such as shrinkage, settlement, and consolidation should also be considered.

Past experience and a review of the literature indicate that drying times for slurry will vary from 1 1/2 to 2 months for 6-inch lifts to 3 to 4 seasons for 48-inch lifts. The foregoing assumes drying to a slightly above optimum moisture content, which will, of course, vary from the top

to the bottom of the lift, and will vary considerably throughout the lift with a thick layer. It also assumes drying during the warm season of the year; during the winter months sufficient area will have to be provided for storage.

In the following paragraphs, drying and processing of slurry in thickness of 6 inches or less, 12 to 18 inches, and 18 inches and above will be discussed. It is assumed in all cases that a sufficient natural surface crust of the pond bed exists or has been developed.

Before the slurry can be processed, time must be allowed for decanting of the excess water into retention ponds. At the first sign of a scum forming on the surface of the material, which is expected to require two or three days, the slurry processing may begin.

With a six-inch slurry thickness, evaporation will be rapid, settlement and consolidation will be minimum, and shrinkage will be low. Equipment should be able to aerate (break up the material to allow maximum exposure to the air) this thickness rapidly; therefore, the processing time will be short. The material should be aerated approximately every two days. Processing should take four to six weeks.

Once the material has been dried back to just above optimum moisture content, compaction can begin. If the material is allowed further drying, the moisture content could become too low to achieve the desired degree of compaction. If this occurs, the costly process of adding water to moisture-condition the material will be required. With a thin layer of the material near optimum moisture content, the desired compaction could be achieved using conventional equipment and methods.

Placing the slurry in a thickness of 12 to 18 inches will require from several days to two weeks for the decanting and initial drying process to take place. Shrinkage and consolidation will be greater, slightly decreasing the fill thickness.

The optimum thickness for processing will fall within the 12 to 18 inch range and is dependent upon the equipment used. The limiting factor is the clearance available underneath the equipment body. If the slurry thickness exceeds this clearance, the equipment's efficiency will decrease rapidly and may even lead to immobility. Experience has shown that the most common pieces of equipment with which satisfactory results have been attained have clearances of approximately 14 inches.

When the material has been aerated by equipment, to bring the moisture content to near optimum, compaction can begin. However, the thickness of the material will prevent obtaining the desired degree of compaction at the bottom of the fill if the effort is applied only to the top. Therefore, half the fill thickness will have to be either hauled off and used elsewhere or windrowed to the side. In either case, the bottom half is then compacted using conventional equipment. If the material has been windrowed, it can be placed back on top and compacted. If it is desired to remove the top half, light self-loading scrapers or loaders and dump trucks can be used. The excess material can be used to construct haul roads, dikes, or working pads in other areas.

Slurry that is placed in thicknesses greater than 18 inches will require special handling techniques. Because such depths tend to immobilize conventional processing equipment, it is not recommended to try to aerate the fill with this equipment. Specialized equipment may be designed that will work satisfactorily; however, none has been developed to date.

If a layer of slurry has been placed in a thick lift which cannot be worked,the following processing procedures may be used: Once the slurry fill has been decanted and while still in semifluid state, a breach in the pond dikes is made and the slurry is allowed to flow into adjacent ponds. Experience indicates that for four feet of slurry, approximately three months of drying time is required for the material to become cohesive enough to allow it to spread out into a thin layer. It is desirable to do the spreading while the material is semifluid so it will spread by itself, but spreading can also be accomplished later when the material becomes more

cohesive. In the latter case, the dike must be breached and the equipment used to spread, aerate, and haul the material when it is ready for compaction.

For successful processing of thick fills, sufficient land adjacent to slurry pond is required to spread out and aerate the slurry fill. This area must have a satisfactory natural surface crust or one must be developed. However, this type of processing has the advantage that it does not require the extensive leveling that is important in the previous methods, unless differential settlement becomes a consideration.

As noted in Section 6.3.6, evaporation plays a key role in determining when the material can be processed, and evaporation data should be used as guide for determining the working season. The working season should be the five to seven months of the year with the highest evaporation rates. This generally limits operations to the months of April through September, although this may vary for a specific site and a specific year. Beyond these dates, disposal operations can continue, but the efficiency of slurry processing is greatly reduced and costs may increase substantially. However, other work such as slurry placement and some site preparation can be done during the remaining months.

There are other methods for dewatering dredged spoils which can possibly be used in lieu of or in addition to evaporation. In the Northwestern University report, (Ref. 57) for instance, reference is made to such techques as gravity and vacuum drainage, electro-osmosis, sand drains, and consolidation under an applied load. Considering the large volumes of material involved, however, it is doubtful that these methods would be economically feasible in an operation of the size contemplated here.

C. <u>Equipment</u> - Experienced gained at the Redwood Shores project near Redwood City, California indicates that the most satsifactory pieces of equipment for movement and aeration of the slurry material are small tracked dozers of the Caterpillar D6-C size for the bulk of the work and the John Deere JD450-B size for the very soft areas. These tractors should be equipped with 24-inch tracks and two-inch grousers to increase traction and reduce pressure. Larger and heavier equipment can be used if the

surface crust is of sufficient strength and wearability to prevent deterioration of the working surface or of successive fill layers. Experimentation will be required at each site to determine how large the equipment can be.

Specialized aeration equipment has been used with some success, especially large multiple discers towed behind tractors. Other equipment will have to be evaluated on an experimental basis, with specific attention given to performance and the effect on the surface crust.

For compaction of clayey dredged spoils, a sheepsfoot roller towed by a tractor appears to give the best results. Self-propelled compactors have a tendency to become bogged down in wet clays. If the material is somewhat silty or sandy, the self-propelled compactors should be considered In very sandy slurry fills, rubber-tired rollers will provide good compaction results and can also be used to seal off clayey areas if rain is imminent.

6.3.8 Site Development Examples

A. General - To arrive at comparative costs for development and operation of land disposal sites, two representative sites were chosen for conceptual development. The first is representative of the North Bay sites and includes the lower Petaluma site and part of Tubbs Island; the second is representative of the Delta islands and includes the eastern part of Sherman Island and all of the adjacent Jersey Island. These sites are shown on Plates VI-9 and VI-11 respectively.

The site configurations were chosen so that the areas would be approximately equal (7400 acres for the Petaluma site and 7200 acres for the Delta site). The Petaluma site would have a capacity of 119,400,000 cubic yards and the Delta site 116,100,000 cubic yards if the dredged material were placed in a 10-foot thickness, and the ratio of shoal to disposal site volumes were 1:1. Assuming a ratio of shoal volume to disposal site volume of 2:1, such as it could be if the material were conditioned as described in Section 6.3.7, the capacities of the sites

would be 238,800,000 cubic yards for the Petaluma site and 232,200,00 cubic yards for the Delta site. Therefore, either site could hold the twenty year total of material used for this study (Chapter III). The sites could, of course, accommodate more than this volume because of consolidation of underlying soils, but it was assumed that a 10-foot lift thickness would be the maximum which could be placed in a 20 year period because of drying requirements.

Other criteria for selecting the sites were:

- Access - The Petaluma site is ideally located near the center of gravity of Bay dredging and could be reached by pipeline from the San Pablo Bay transfer point or a dredged channel up the Petaluma River. The Delta site is farther from the center of dredging activity, but could be reached from the deep water channels of the San Joaquin or Sacramento Rivers or by pipeline from San Pablo Bay.

- Size - In addition to the 7000+ acres delineated for this study at each site there are many thousands of acres of similar land adjacent to both.

- Topography - Both sites are relatively flat and would require a minimum of site leveling.

- There do not appear to be major adminstrative or environmental restraints to development, although these factors would have to be subject of further study.

One other potential site which was considered earlier, Montezuma, was not explored in detail in the present study because of its smaller size (3500 acres), and the fact that a site review revealed that site preparation work would be extensive.

B. Petaluma Site - This site, shown in its present state in Plate VI-9 and as conceptually developed on Plate VI-10, was described in detail in

earlier sections of this chapter. Some of the main restrictions to development are the high tension power lines crossing the site which will have to be protected by jacketing the tower legs with concrete or by raising the towers.

It is proposed to accommodate surface drainage from the hills to the east by diverting it into channels across the pond area as shown in Plate VI-10 The water would have to be pumped over the levee at locations as shown on the drawing or culverts with flapgates provided through the levee. Site preparation would consists of filling and levelling as described in Section 6.3.3.

It was assumed for this study that existing peripheral dikes will require repair work. Also, they will have to be built up as filling progresses and subsidence takes place. The railroad and highway crossing the site will also have to be protected by dikes.

Primary ponds will be laid out using the criteria of Section 6.3.6. In general, they are oriented in a north-south direction to decrease the effect of turbulence caused by the prevailing westerly winds, and are configured with an approximate length to width ratio of 5:1. Because of adverse topography, they could not be laid out with the inlet at the south end, as suggested in Section 6.3.6, but the effect of the north wind is not as critical here as in Delta. The dikes forming the ponds will be built in increments every three or four years, providing adequate freeboard at all times, as outlined in Section 6.3.6.

Access to the site for the slurried material would probably be by pipeline from the San Pablo Bay transfer station as shown on Plate VI-10. Another alternative would be to use the turning basin shown in the same drawing, which would in addition require dredging and maintenance of a deep water channel in the Petaluma River. The distribution pipelines would be laid out as shown on Plate VI-10 with outlet gates at the entrances to the ponds. The effluent from the ponds would be drained off by weirs or sluices with removable stoplogs into ditches leading to the secondary ponds for later discharge to the Bay.

TABLE VI - 3

Costs associated with the development and operation of this site have been estimated to be as follows:

Capital Costs*

Acquisition	7400 acres @ $1000/acre =	$ 7,400,000
Dikes, weirs, ditches		6,000,000
Distribution System		2,500,000
Drainage		200,000
Utility relocation/protection		700,000
	Total	16,800,000
Annual Capital Cost	@ 6 7/8 % interest (20 yrs) =	1,570,000
Average Annual O & M Cost		300,000
	Total	$1,870,000

Site Volume = 119,400,000, cu. yds

or approximately 119,400,000 ÷ 20 = 5,970,000 cy per year

Unprocessed Material:

If air dry volume = 60 % of shoal volume,

Volume deposited per year $= \frac{5,970,000}{0.6} = 9,950,000$ cy

Unit Site development cost = 1,870,000 ÷ 9,950,000 = $0.19 per cy

Processed Material

Additional Costs:

(1) Site preparation @ $500 per acre

7400 x 500 = $3,700,000

or

346,000 per year (20 years @ 6 7/8%)

* The turning basin/rehandling facility is assumed to be a transfer station and its cost was included in the transportation cost of the system in which it was used.

Processed Material (Contd.)

(2) Processing cost = 0.40 per cy

Assuming 50 % reduction in volume due to processing

$$\frac{5,970,000}{0.5} = 11,940,000 \text{ cy per year}$$

Costs

Development		= $1,870,000 per year
Site preparation		346,000
	Total	$2,216,000

$2,216,000 ÷ 11,940,000	=	$ 0.19 per cy
Processing cost		0.40 per cy
	Total	$0.59 per cy

C. *Sherman/Jersey Island Site* - This area was also discussed in detail earlier in this chapter. It is shown in its present state in Plate VI-11 and as conceptually developed in Plate VI- 12 . As can be seen from Plate VI- 11 , there are numerous power lines, gas lines, and gas wells on Sherman Island, especially the western part; this was the reason for planning the pond location on the eastern half of the island and on Jersey Island, which is relatively clear of obstructions.

The question has arisen as to the possible effect of the fill on the natural gas production from the formations under the Delta. It was found that because of the great depth of the producing horizons (Ref. 39), deposition of mud should have no effect upon gas production. Provision would have to be made, however, for raising or diking off the above-ground part of the wells and relocating or protecting gas pipelines.

Conceptually, a diked-off corridor for the high voltage lines crossing the disposal areas on the eastern part of Sherman Island and on Jersey Island was provided. Peripheral levees on the islands were assumed, as in the case of the Petaluma site, to require repairs and maintenance. Ponds and interior dikes will be laid out and constructed in a manner similar to those on the Petaluma site, and with distribution and drainage facilities as shown on Plate VI-12. Ponds are laid out in a north-south direction, have a length to width ratio of approximately 5:1, and have their outlets on the north ends.

Access to this site would be by pipeline from the San Pablo Bay transfer point, from a barge-mounted transfer unit moored adjacent to the site, or from a rehandling facility at the turning basin shown on Plate VI-12.

Costs associated with the development and operation of this site would be as follows:

Capital Cost*

Acquisition	7200 acres @ $800/acre	$ 5,760,000
Dikes, weirs, ditches		5,300,000
Distribution System		2,600,000
Drainage		200,000
Utility relocation/protection		500,000
	Total	$14,360,000
Annual capital cost @ 6 7/8 % interest (20 years) =		$ 1,340,000
Average annual O & M cost		300,000
	Total Annual Cost	$ 1,640,000

* As at the Petaluma Site, the turning basin/rehandling facility was included in previous calculations as part of the transport system.

Site Volume = 116,100,000 cubic yards

or approximately 116,100,000 ÷ 20 = 5,805,000 cy/yr

Unprocessed Material

Assuming volume of air dried material in disposal area = 60% of shoal volume

Volume deposited per year $= \frac{5,805,000}{0.6} = 9,675,000$ cy

Unit site development cost $= \frac{1,640,000}{9,675,000} = \$0.17/\text{cy}$

Processed Material

Additional Costs:

(1) Site Preparation @ $2000 per acre

7200 x 2000 = $14,400,000

or

$1,350,000 per year (20 years @ 6 7/8 %)

(2) Processing costs = $0.40 per cy

Assuming 50% reduction in volume due to processing

volume $= \frac{5,805,000}{0.5} = 11,610,000$ cy per year

Costs:

Development		= $ 1,640,000 per year
Site preparation		= 1,350,000 per year
	Total	$ 2,990,000 per year
	$\frac{2,990,000}{11,610,000}$	=$ 0.26 per cy
Processing Cost		= 0.40 per cy
	Total	= $0.66 per cy

6.4 ENHANCEMENT AND FUTURE USE

6.4.1 General - If, after a review of all perinent factors, it is determined that dredged material disposition will be on land, adequate consideration should be given to the use and improvement of the areas during and after placement of the material. It would most likely be environmentally and/or esthetically unacceptable, and unsound from an engineering standpoint, to leave large areas of dredge spoil without some degree of improvement. Also, the concept of land disposal of dredged material may find greater public acceptance if it can be shown that disposal areas can be improved after placement of dredged material.

The degree of enhancement or improvement provided at a disposal site will have a bearing on the future use of the area and the cost of the improvement. Depending on the degree of improvement, certain uses of the area may be possible, while other uses may be precluded because of the characteristics of the improved material. For example, if the dredged material is allowed to dry without compaction and given a minimum of surface treatment with construction equipment, it might be used for development as a wildlife habitat if revegetation is encouraged. If the soil is leached and/or topsoil imported, a park, recreational area, or agricultural area might be developed. Finally, if the material is compacted as described in earlier sections of this chapter, it would be possible to use it as an engineered foundation for certain types of structures.

Some of the benefits from disposal area improvements will be measurable, such as increased land values and income from the property, while others will be intangible such as aesthetic and wildlife enhancement. Additional costs will be incurred, regardless of the degree of improvement or enhancement, and the goal of a well-engineered program should be to arrive at a favorable ratio of benefits to costs.

6.4.2 Open Space Use - Although the spoil disposal area, or portions of it, will be removed from its present use for the period during which the

FIGURE VI - 5

material is being placed, it could still be classed ultimately as "open space" if it is used for agriculture, recreation, or wildlife habitat purposes. These uses are discussed in the following paragraphs.

- Agricultural Use - In the Waterways Experiment Station (WES) publication on dredged material confinement (Ref. 52), it is noted that dredged material could possibly serve as a growing medium for many crops, and reference is made to successful use of dredged material for this purpose in several locations, although the characteristics of the material are not described.

To assess the feasibility of using dredged material from San Francisco Bay as an agricultural soil, laboratory analyses of samples of sediments from the dredging sites (Appendix B) were reviewed by Professor C.C. Delwiche of the Department of Soils and Plant Nutrition of the University of California at Davis. Dr. Delwiche concluded that there is nothing in the laboratory data which would exclude the use of the sediments for a number of applications, including use as a soil directly for agricultural application or as a fill covered with tillable soil. His specific observations:

- Textural Analysis - The material consists largely of silt and flocculated clays characteristic of most basin and estuarial sediments. Data on exchangeable cations (not including hydrogen ion) correlate the fact that clay content is high. Organic content is assumed to be less than 10%.

- Sodium Content - Exchangeable sodium is high, giving calculated values as follows:

Lab. No. & Source		% Exchangeable Na*
20475	San Francisco	57
20476	Redwood City	61
20478	Oakland	67
20483	Mare Island Strait	59

* Calculations based upon the assumption that Na^+, K^+ and Ca^{++} were principal adsorbed cations with no significant quantity of H^+ or other cations being present.

• Heavy Metals - In general, heavy metals data are not disturbingly high, when compared with proposed EPA guidelines for sediment pollutants. Figures on cadmium appear somewhat high. This may reflect the common tendency for cadmium to be concentrated in sediments. Atomic absorption analysis for cadmium is subject to a number of interfering phenomena which may introduce error, however, so these values may be deserving of more careful study. Figures given (with the exception of Sample 20476, Redwood City) are below an arbitrarily assumed maximal value of 0.5 ppm for soils for agricultural application.

Data on mercury are not included.

• Sulfide Content - Available data do not indicate the extent to which insoluble sulfides may be present in this material. Iron sulfide, if present in significant quantities, could result in the formation of highly acid "cat" clays upon exposure of such materials to air.

• Tentative Conclusions - Available data, although they do not exclude the possibility of application of this material for agricultural use, suggest the following:

1. Exchangeable sodium is sufficiently high to classify these sediments as "sodic." The calcium content is comparatively high, suggesting that reclamation for direct agricultural use would be possible.

2. The comparatively high exchange capacity for all samples indicates the possibility of a considerable (but not necessarily objectionable) organic content.

3. The high exchangeable sodium values indicate that the material is dispersed. It is possible therefore that for agricultural application the addition of gypsum would be necessary to encourage flocculation and aid in consolidation and drainage.

• Recommended Future Study - Depending upon intended application it would be desirable to initiate further studies directed toward answering some questions posed by available data. These include (not necessarily in order of priority):

1. Further careful study of cadmium content.
2. Determination of mercury content.
3. Determination of sulfide content including insoluble (e.g., iron) sulfides.
4. Direct field trial of test plots of the material. Such trials on modest 10' x 10' x 6" plots including plant growth studies and analysis of plant tissues probably would be most revealing.

In the same WES publication previously cited, (Ref. 52) the practice of removing and stockpiling topsoil, and later replacing the topsoil over the dredged material is described. Another possibility for improving the value of the dredged material as an agricultural soil is by mixing sand or humus with it to improve its properties as a crop-growing medium. Surplus agricultural products could be utilized as admixtures to improve the quality of the dredged material for agricultural use. For example, rice hulls, which are a surplus commodity at the Port of Sacramento, could possibly be used. Another interesting possible utilization of surplus material in conjunction with dredge spoils was suggested during discussions with personnel involved in the Bay Delta Resource Recovery Demonstration project, which is a project to investigate the use of processed solid waste from the Bay Area for strengthening levees in the Sacramento-San Joaquin Delta. Study could be made of the possibility of mixing the dredged material with the processed solid waste to improve the structural characteristics of the latter material and also of using the combination of the two for agricultural uses. It is conceivable that processed sewage sludge could be used for the same purpose

• Wildlife Habitat Creation - One of the studies being conducted by the San Francisco District, as part of the Dredge Disposal Study (Ref. 1) is to determine the potential for creating artificial marshland in the Bay, which involves the partial filling of abandoned salt evaporation ponds with dredged material. A similar operation could be carried out at some of the low-lying disposal sites noted earlier in Section 6.2. Wildlife habitat could also be created by the construction of "spoil islands" as described in Ref. 51, although this utilization of dredged spoil was felt to be beyond the scope of our study. Habitat could also be created at disposal sites above the tidal range by encouraging the growth of natural vegetation and creating feeding and nesting areas for birds, feed and cover for small game, etc.

• Recreational Areas - As California becomes increasingly urbanized, it is recognized more and more that there is a growing need for parks and recreational areas. The WES report (Ref. 52) notes several instances of actual or proposed utilization of disposal areas in other parts of the country for parks. Other recreational uses could include golf courses, playing fields, marinas, fishing areas and many others.

Recreational use of a dredge disposal area would undoubtedly have a high degree of public acceptance. It would also have the advantage that a minimum expenditure would be required for compaction or consolidation of the dredged material.

6.4.3 Engineered Fill- The use of the conditioned dredged spoil as an engineered fill which could be used for support of structures was discussed earlier in this chapter. Experience obtained at Redwood Shores and elsewhere indicates that light construction can be accomodated on an engineered fill of bay mud. Moore and Chryssafopoulos (Ref. 64) point out that structures and facilities can be designed for sites where substantial future subsidence is expected by one of the following methods: (1) Rigid design; (2) Flexible design; (3) Hinged or articulated design; and (4) design for maintenance.

As noted earlier, the dredged material is predominately a silty clay. One method of stabilization which has been used successfully elsewhere is to mix it with lime. It could be productive to investigate the technical and economical feasibility of this alternative.

6.4.4. Correcting Existing Problems - Placement of dredged material at some sites could correct existing problems such as subsidence, erosion, poor drainage, unstable levees, etc. These benefits would generally accrue and be independent of the ultimate utilization of the site.

Subsidence in the South end of the Bay due to ground water extraction, which was noted in Section 6.2, could be alleviated by placement of dredged fill, if it were properly engineered.

- The use of dredged spoil to prevent or deter bank erosion is noted in Ref. 51, but this use would be limited to selected sites because of the low erosion resistance of most of the dredged material in the Bay.

- An important beneficial use of dredged spoil in the Delta would be to blanket the peat layer to prevent its decomposition by oxidation, since this is a primary cause of subsidence of the Delta islands.

- The use of dredged fill in combination with processed solid waste to stabilize the levees in the Delta was noted earlier

- At many locations around the Bay, areas have been diked off in the past for use as salt evaporation ponds, farmland, etc. Since the diked land is usually below sea level, all surface drainage must be pumped out. If dredged material were placed in such an area, the pumping requirement would be reduced or eliminated.

6.4.5. Use as a Resource - It is possible that dredged material could be used as a resource, by manufacturing building materials from it or using it as fill at another location. Ref. 52 notes studies that have been made to manufacture ceramic aggregate or bricks from dredged material. The use of the dredged material as construction fill at another location from the disposal site appears to be somewhat infeasible because of the rehandling and transportation costs involved, but could be successful in areas where satisfactory fill material is difficult to obtain. This use would materially increase the life of a disposal site.

TABLE VI -

PHYSICAL PROPERTIES OF BAY SEDIMENTS

Location	Apparent Density, gm/cc	Force * to Penetrate, lbs.	Percent Water PW	Percent Water PWW	% Passi #200 Si
San Francisco	1.48	85	74.5	42.7	69
Redwood Creek	1.33	100	172.0	63.3	81
Redwood Creek	1.38	90	140.5	58.5	
Oakland Outer Harbor	1.43	115	123.5	55.3	99
Richmond Harbor Entrance	1.52	185	75.9	43.2	86
San Rafael Creek	1.39	185	113.0	53.0	96
Pinole Shoal	1.64	300**	72.3	42.0	55
Pinole Shoal	1.64	300**	41.3	29.2	
Mare Island Strait	1.30	136	102.0	50.5	99
Suisun Bay	1.64	285	49.3	33.0	48
Napa River	1.61	100	82.0	45.1	64
Petaluma River	1.39	60	111.8	52.8	99

* Loading on 3" core penetrating 2 ft of sediment.

** Estimated from free fall of 145 lb core device through water column.

$$PWW = \frac{PW}{PW + 100}$$

Apparent Densities and Water Contents of Shoal
and Freshly Settled Sediment

Sample	Shoal: Apparent Density, g/cu cm	Shoal: Fraction* Water	Shoal: Conc. of Deposit g/cu cm	Settling Test: Apparent Density, g/cu cm	Settling Test: Fraction* Water	Settling Test: Conc. of Deposit g/cu cm
1. San Francisco	1.48	.720	.742	1.13	.891	.289
2. Redwood Cr. (1)	1.33	.796	.530	1.31	.926	.198
Redwood Cr. (2)	1.38			1.16		
3. Oakland Outer Harbor	1.43	.751	.660	1.14	.928	.190
4.						
5. Richmond Harbor Entrance	1.52	.695	.807	1.26	.858	.377
6.						
7. San Rafael Cr.	1.39	.775	.595	1.20	.894	.282
8. Pinole Shoal (1)	1.64	.622	1.00	1.32	.808	.510
Pinole Shoal (2)	1.64	.622		1.35		
9. Mare Island St.	1.30	.831	.448	1.19	.897	.273
10. Suisun Bay	1.64	.622	1.00	1.37	.790	.556
11. Napa R.	1.61	.640	.954	1.54	.685	.833
12. Petaluma R.	1.39	.775	.595	1.22	.880	.318

*By volume

Daily Coverage by a One Foot Wet Deposit and
Water To Be Evaporated

	Shoal Area	Shoal Volume 1000 cu yds	Area Covered, acres		Water Evaporated, ins.	
			Settled One Day	At Shoal Density	Settled One Day	At Shoal Density
1.	San Francisco	650	70.0	37.2	9.65	5.97
2.	Redwood Creek	1026	61.1	37.2	10.4	7.65
3.	Oakland O. H.	1472	86.9	37.2	10.4	6.64
5.	Richmond H.	2748	53.4	37.2	8.94	5.43
7.	San Rafael Creek	240	52.6	37.2	9.71	7.16
8.	Pinole Shoal	3008	49.0	37.2	7.86	3.86
9.	Mare Is. Strait	3050	41.0	37.2	9.78	8.36
10.	Suisun Bay	1080	44.7	37.2	7.48	3.86
11.	Napa River	840	28.5	37.2	5.22	4.25
12.	Petaluma River	580	46.7	37.2	9.42	7.16
	TOTAL	14,694	Weighted Averages			
		Design Year	52.0	37.2	8.89	5.93
		Average Year	34.8	25.0	8.89	5.93

TABLE VI - 3

FIGURE VI - 1

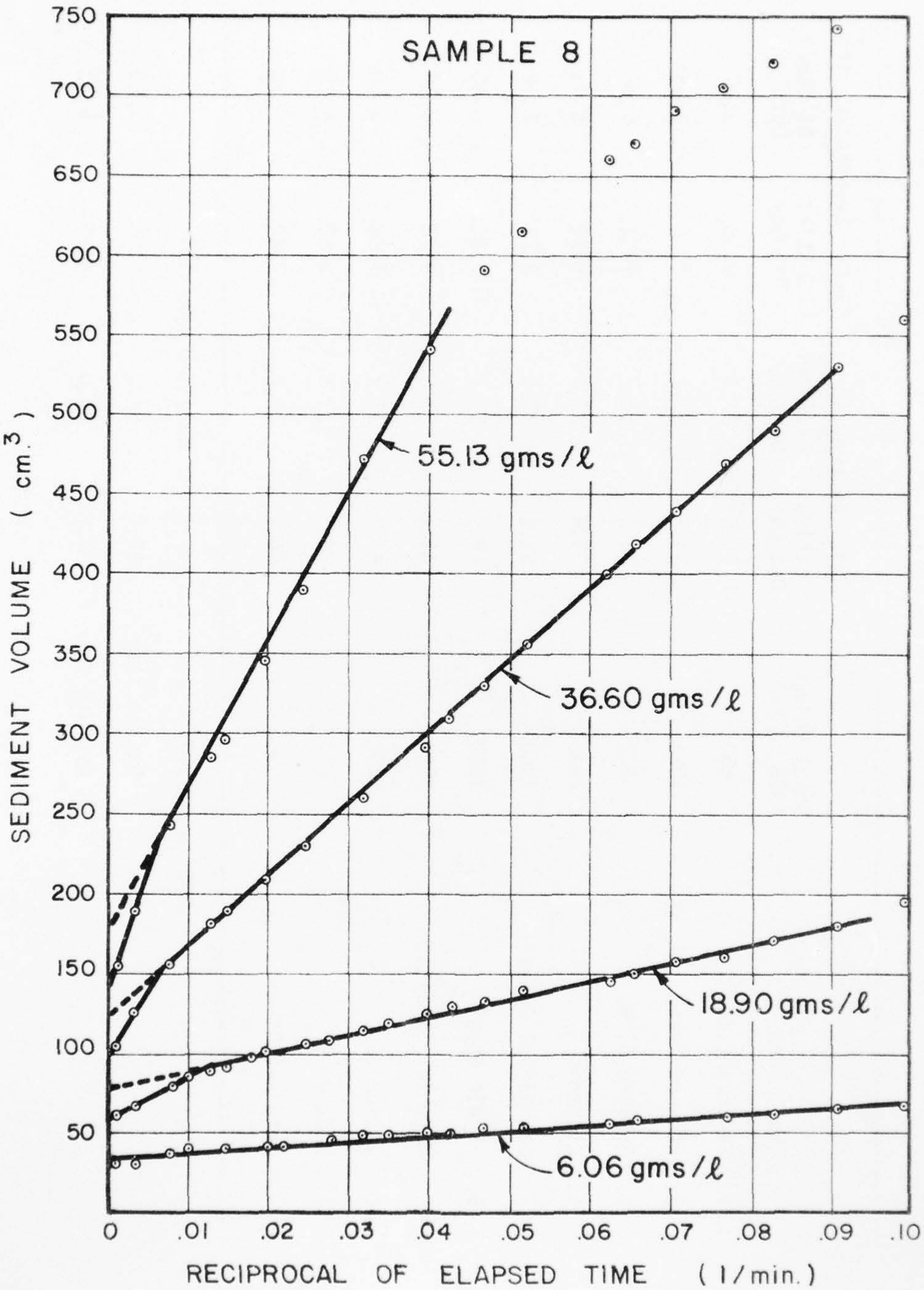


FIG. VI - 1 HINDERED SETTLING TEST

FIGURE VI - 2

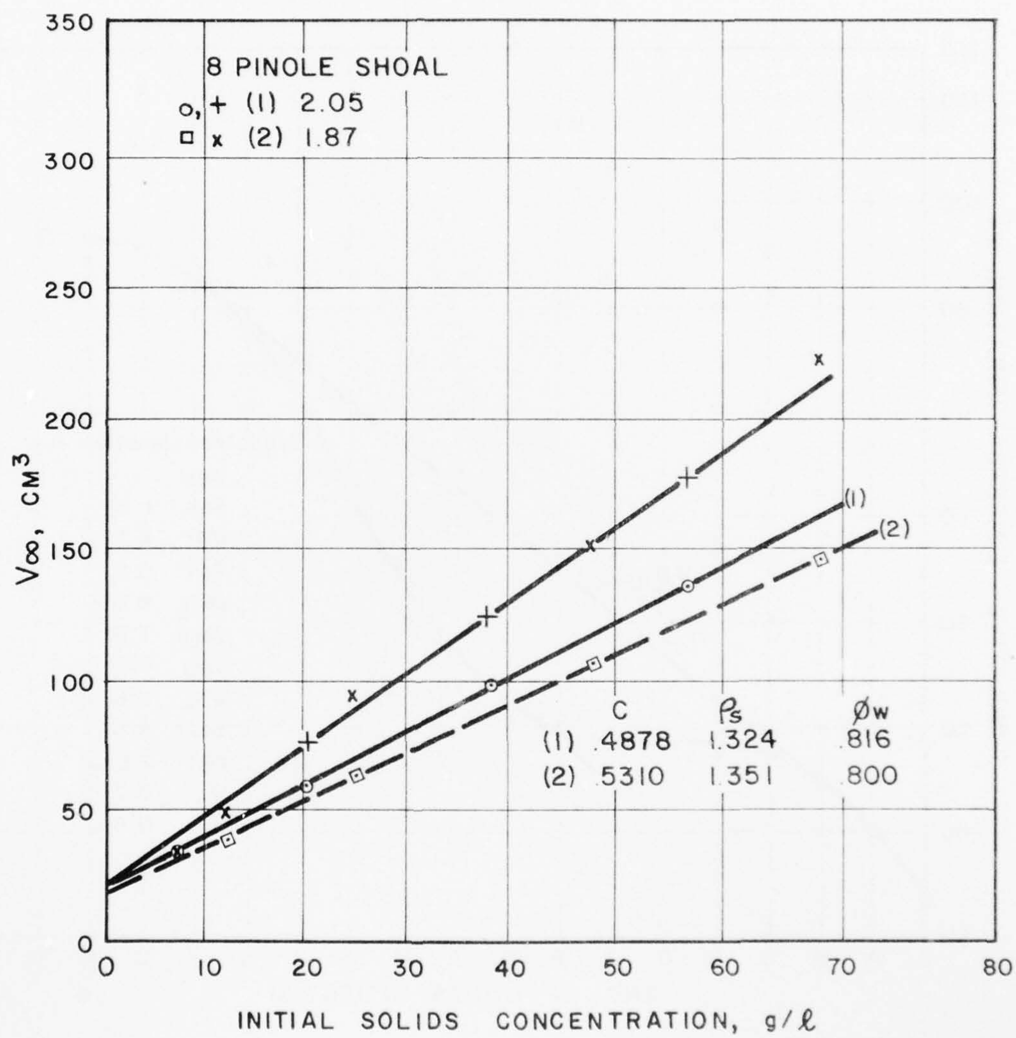


FIG. VI - 2 PLOT OF INITIAL CONSOLIDATED VOLUMES FROM INTERCEPTS OF SETTLING CURVES

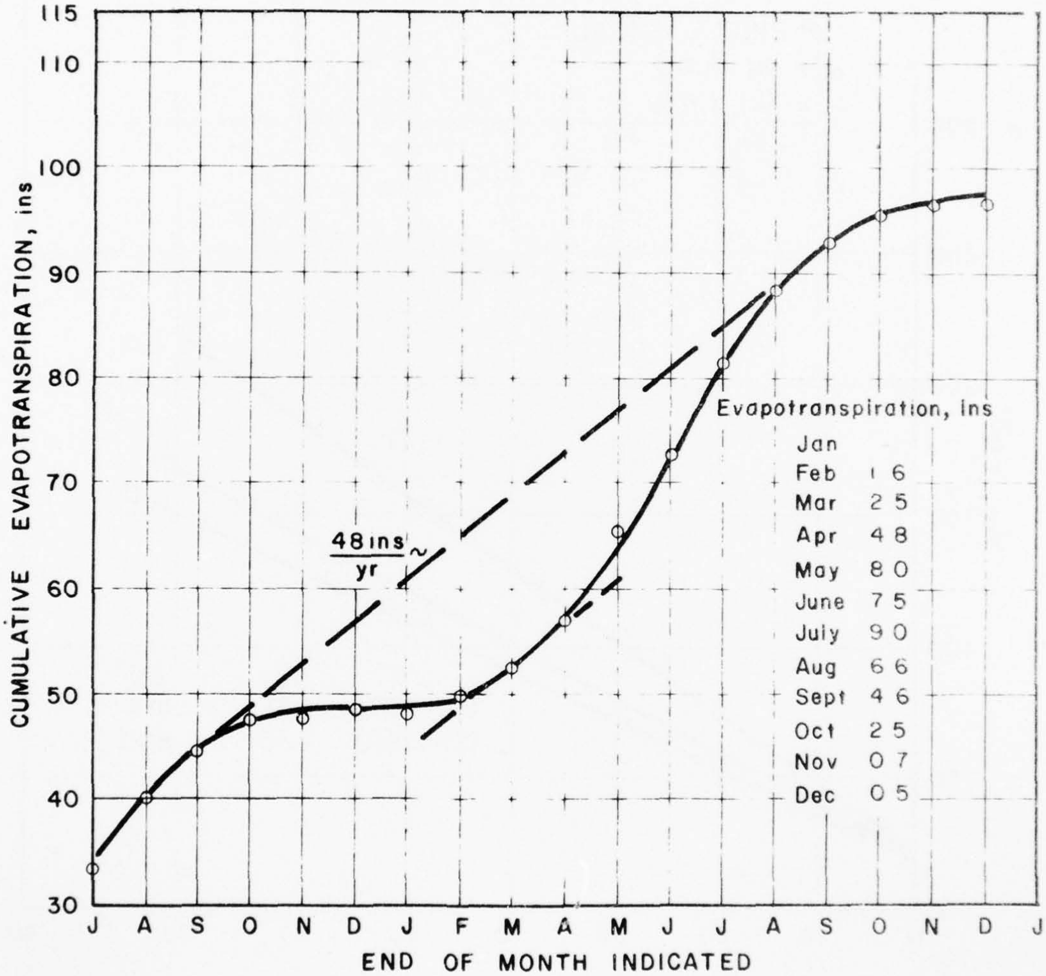


FIG. VI - 3 PLOT OF CUMULATIVE EVAPOTRANSPIRATION MEASURED NEAR THORNTON

FIGURE VI - 4

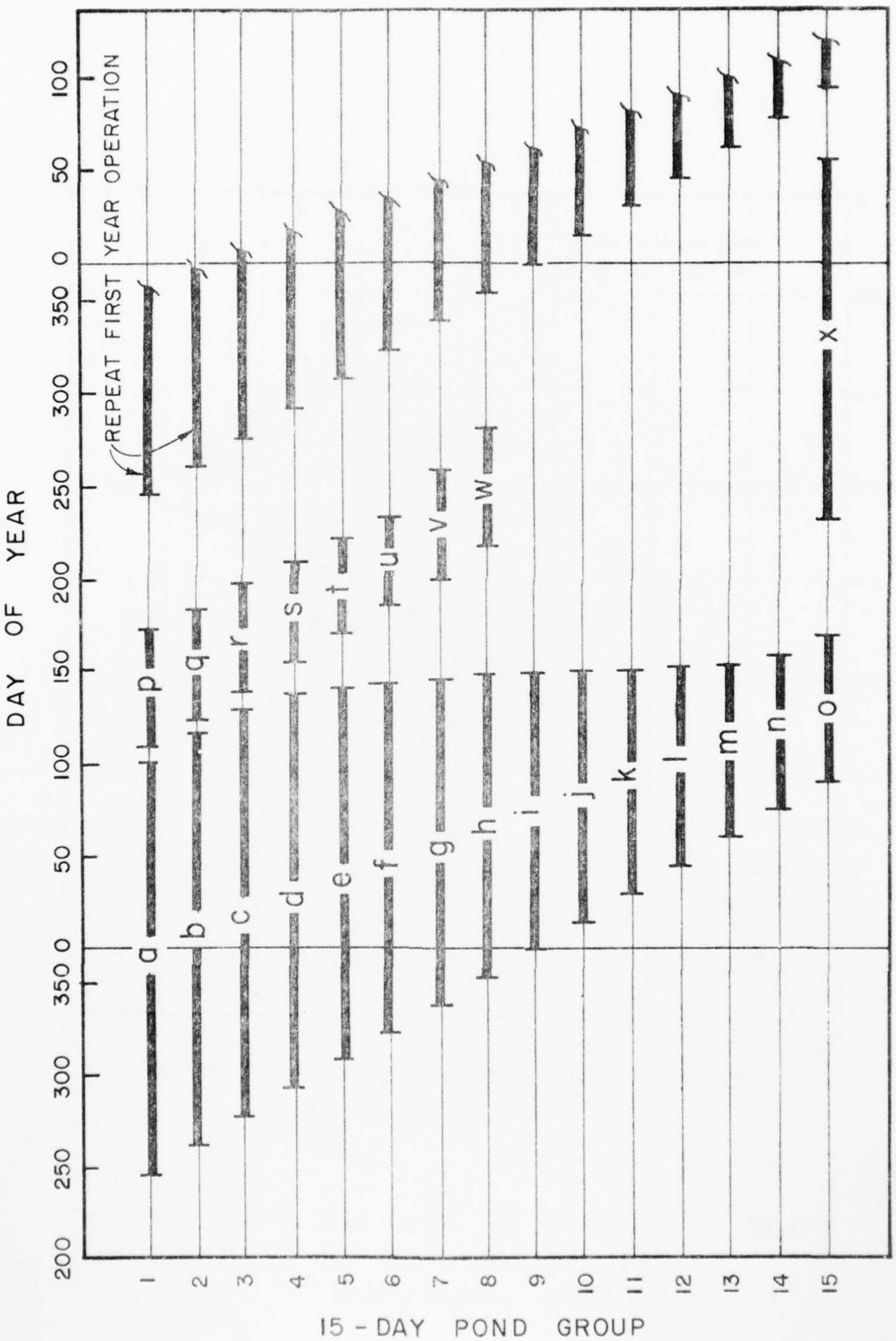


FIG. VI - 4 PLOT SHOWING PRIMARY POND FILLING & DRYING SCHEDULE FOR EVAPORATION OF 12.8 INCHES WATER

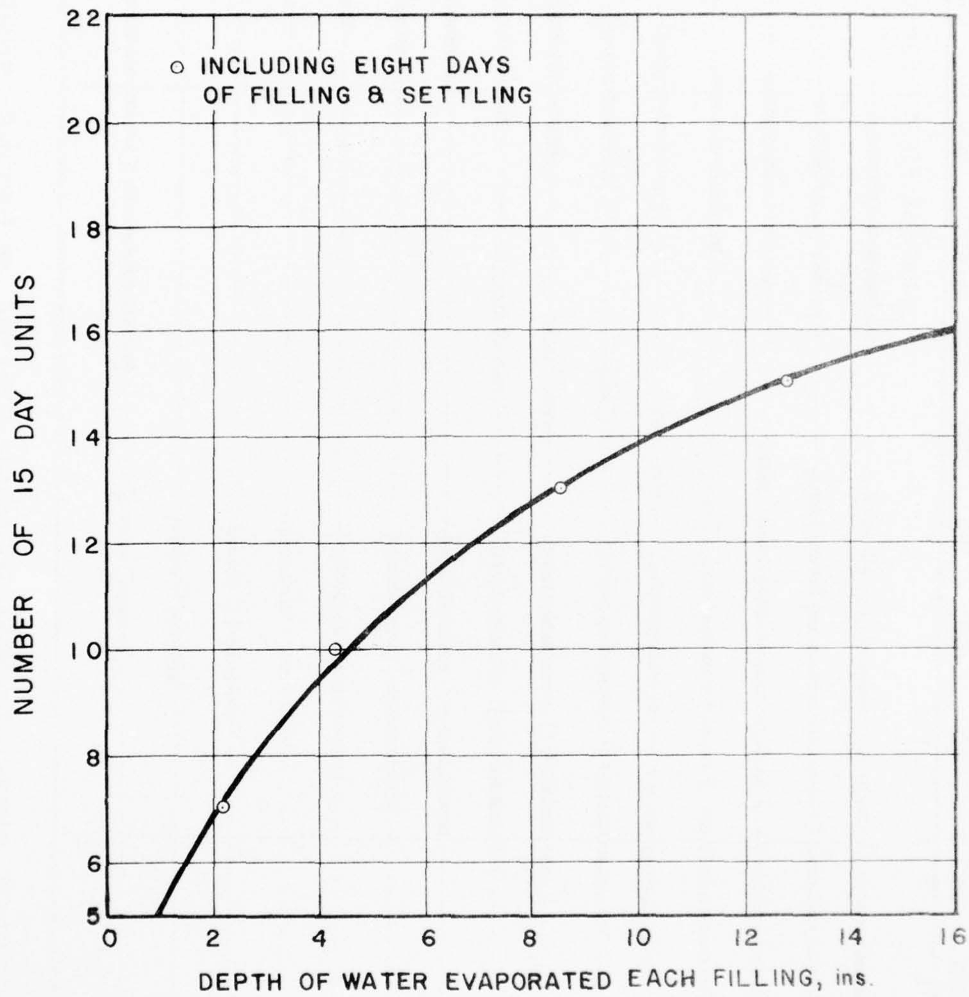
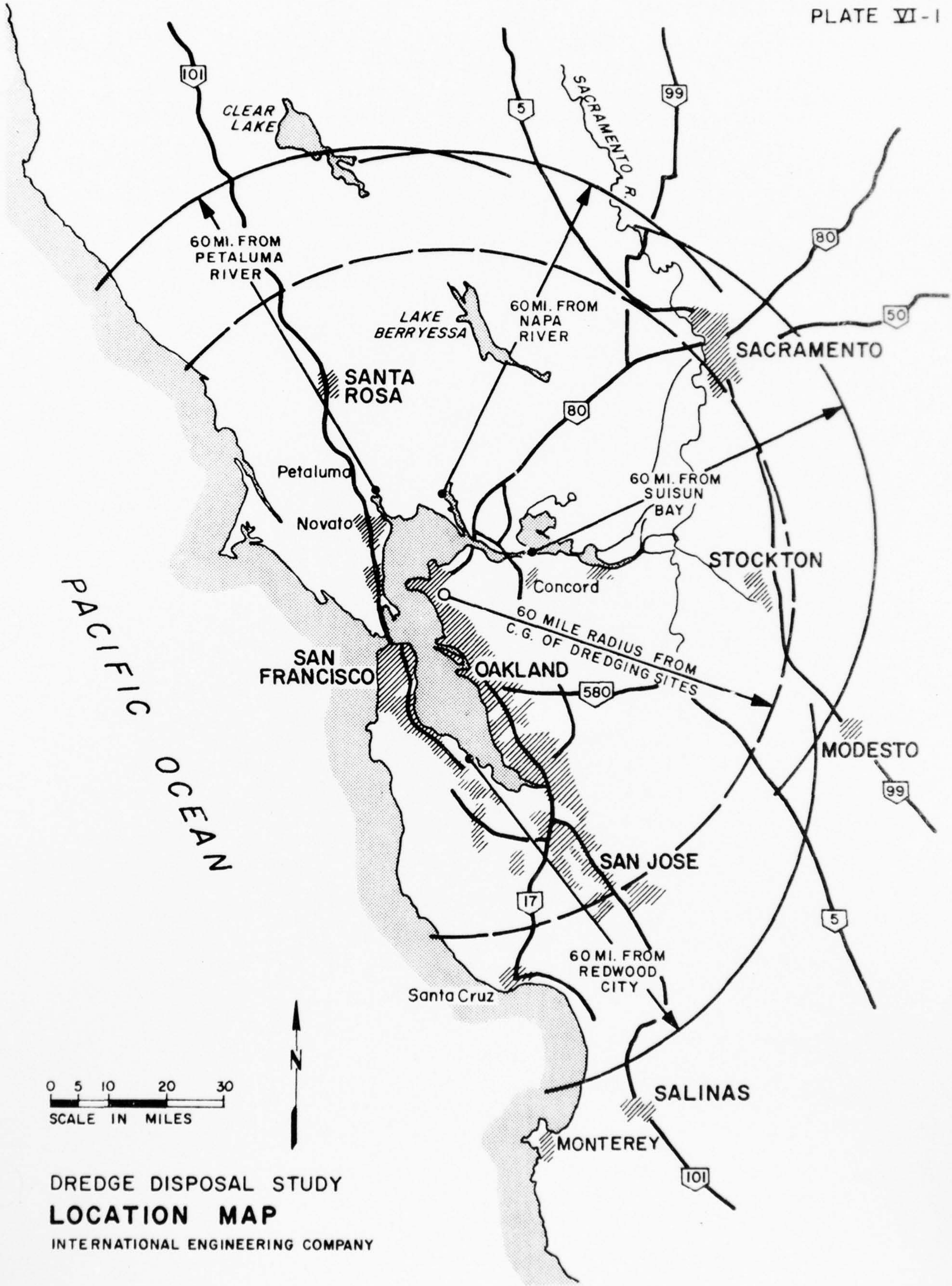


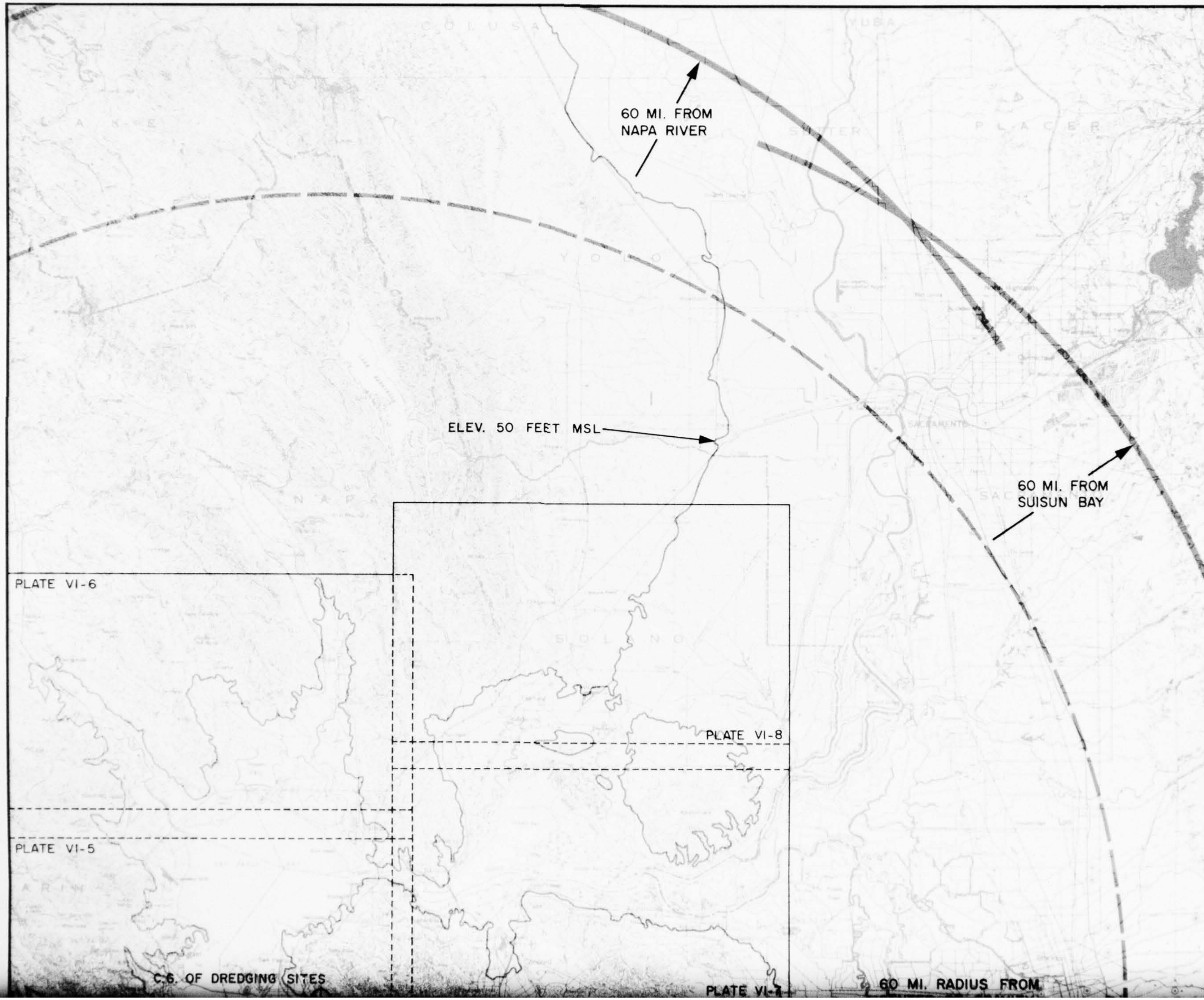
FIG. VI - 5 NUMBER OF POND GROUPS REQUIRED FOR EVAPORATION FOR YEAR AROUND UNIFORM OPERATION



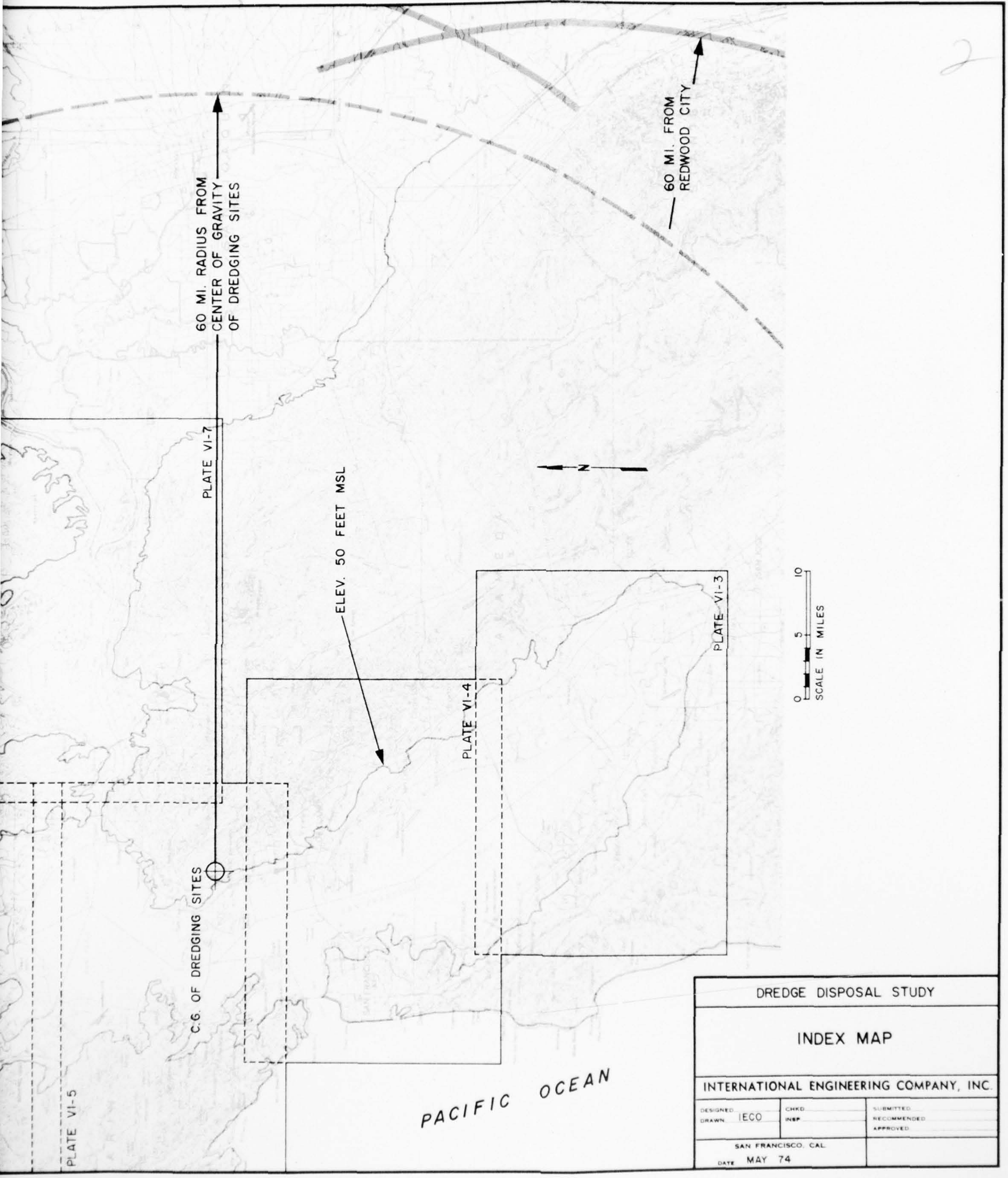
DREDGE DISPOSAL STUDY

LOCATION MAP

INTERNATIONAL ENGINEERING COMPANY



COLUSA
YUBA
LAKE
SUTTER
PLACER
YOLO
NAPA
SOLANO
SACRAMENTO
60 MI. FROM
NAPA RIVER
60 MI. FROM
SUISUN BAY
ELEV. 50 FEET MSL
PLATE VI-6
PLATE VI-5
PLATE VI-8
PLATE VI-7
C.G. OF DREDGING SITES
60 MI. RADIUS FROM

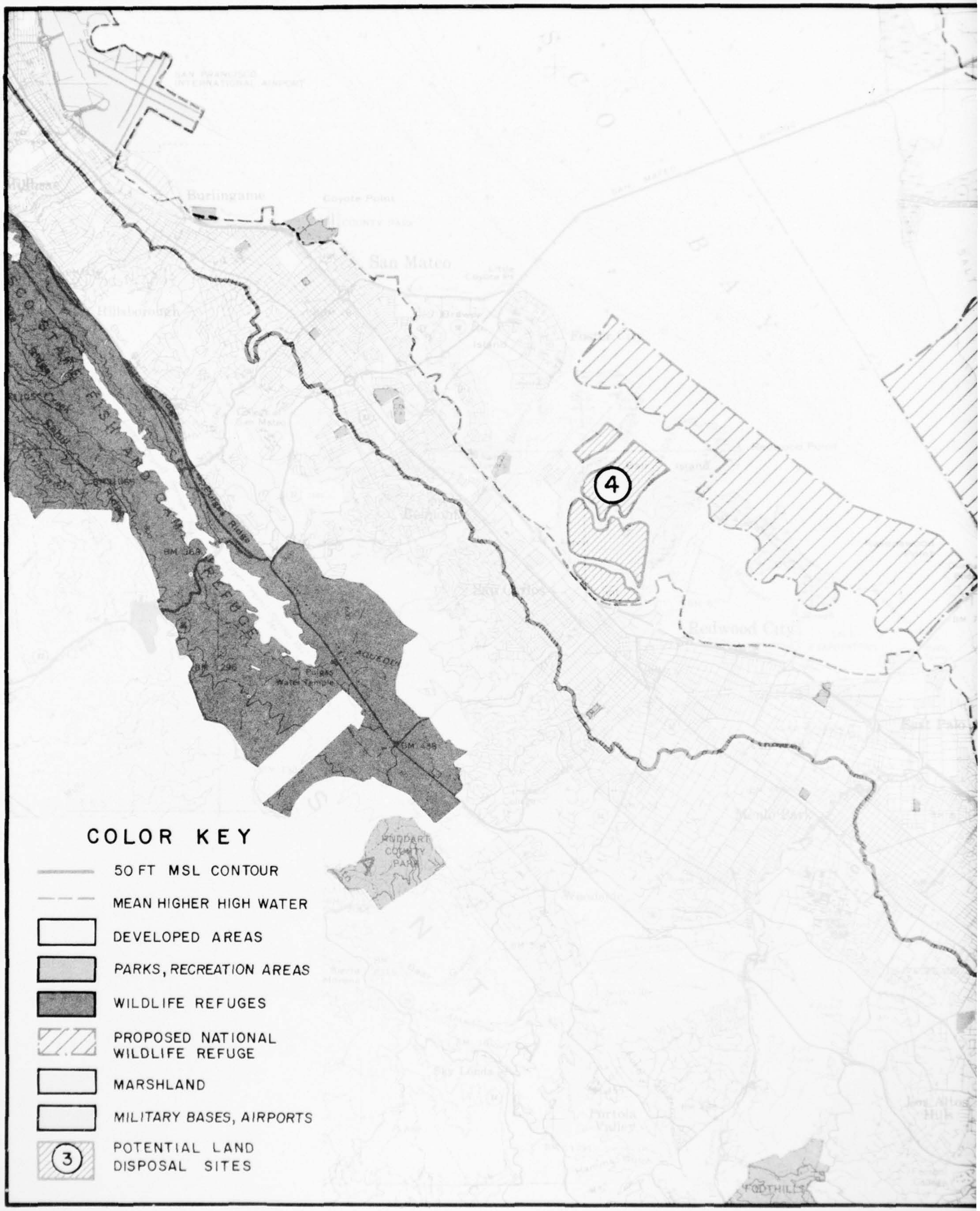


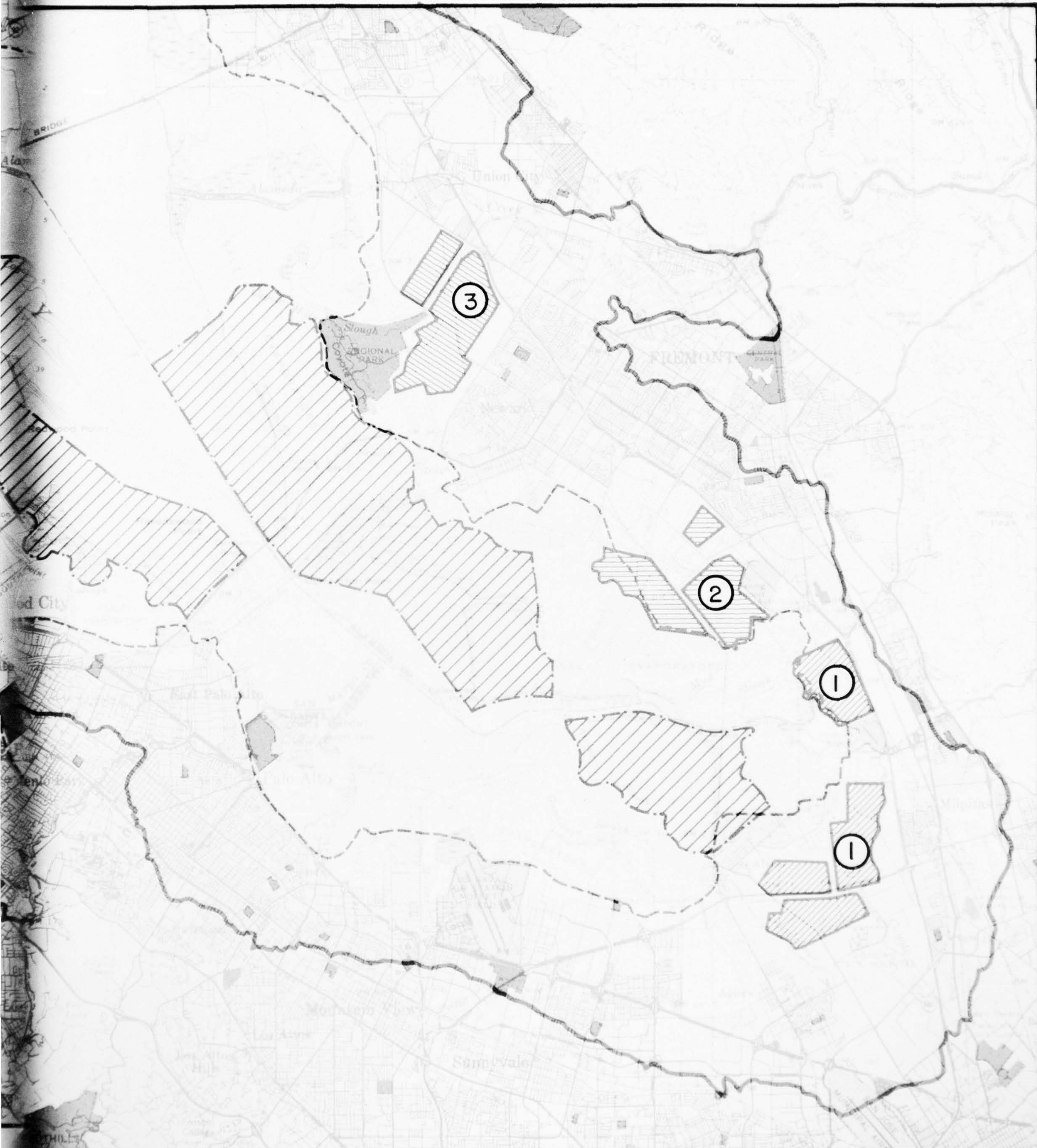
DREDGE DISPOSAL STUDY

INDEX MAP

INTERNATIONAL ENGINEERING COMPANY, INC.

DESIGNED	CHKD	SUBMITTED
DRAWN IECO	INSP	RECOMMENDED
		APPROVED
SAN FRANCISCO, CAL. DATE MAY 74		

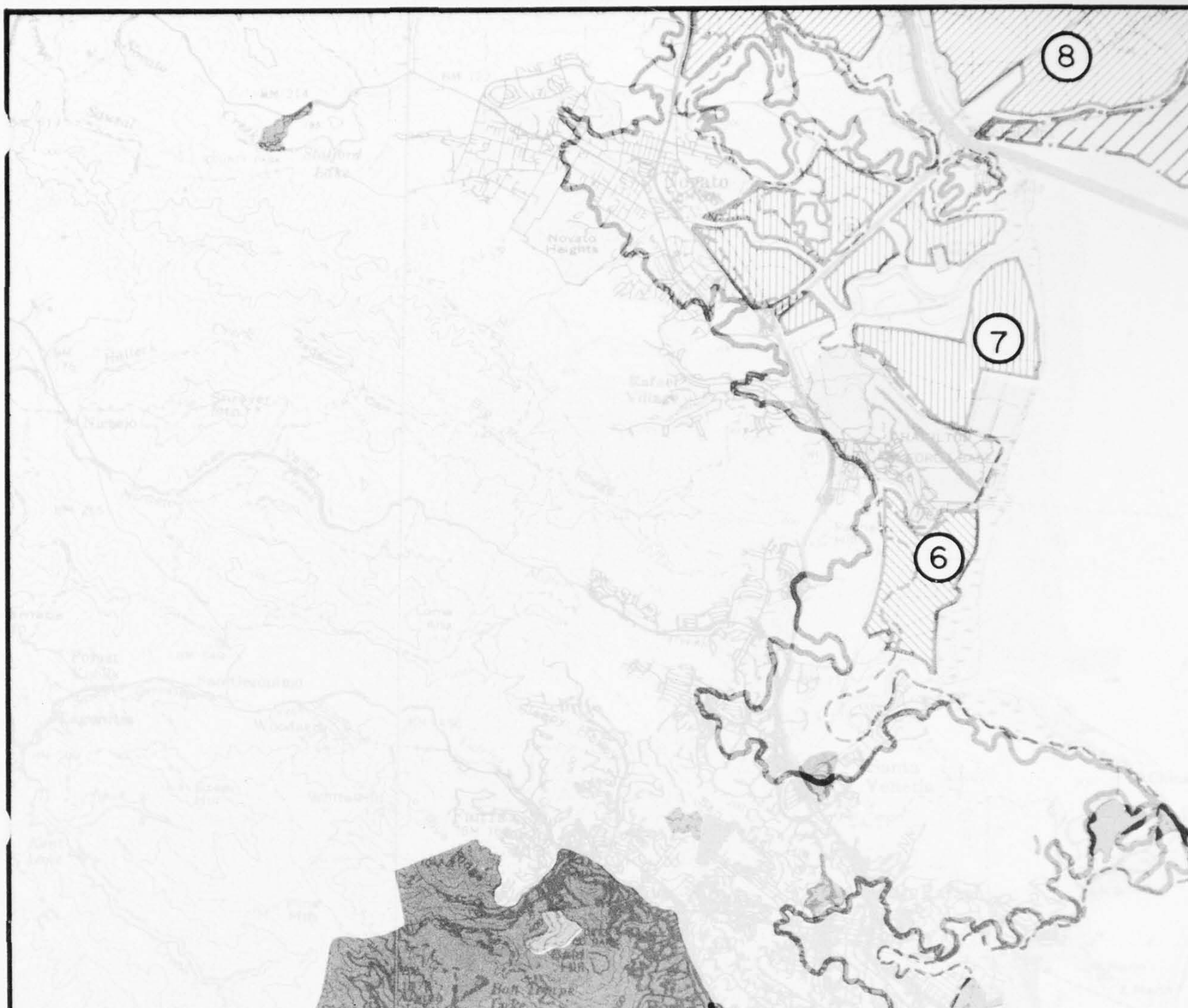

SAN FRANCISCO INTERNATIONAL AIRPORT
Burlingame
Coyote Point
San Mateo
Hillsborough
Belmont
San Carlos
Redwood City
Menlo Park
Portola Valley
Los Altos Hills
Pulgas Water Temple
HUDDART COUNTY PARK
FOOTHILLS
4
COLOR KEY
50 FT MSL CONTOUR
MEAN HIGHER HIGH WATER
DEVELOPED AREAS
PARKS, RECREATION AREAS
WILDLIFE REFUGES
PROPOSED NATIONAL WILDLIFE REFUGE
MARSHLAND
MILITARY BASES, AIRPORTS
3
POTENTIAL LAND DISPOSAL SITES



PREPARED BY INTERNATIONAL ENGINEERING COMPANY


SAN FRANCISCO
BERKELEY
Belvedere
Tiburon
Sausalito
Angel Island STATE PARK
FORT CRONKHITE
FORT BARRY
FORT BAKER
GOLDEN GATE PARK
Daly City
Brisbane
South San Francisco
Pacifica
BAY
FOR COLOR KEY
SEE PLATE VI-3


5
5
BERK
OAKLAND
Alameda
Alamed
Farm
SHIPYARD
Point
San Leandro Hills
REGIONAL
PARK
Lake Chabot
San Lorenzo
Hayward
Castro Valley
AIRPORT


8
7
6
Novato
Novato Heights
FOR COLOR KEY
SEE PLATE VI - 3

AD-A038 313 CORPS OF ENGINEERS SAN FRANCISCO CALIF SAN FRANCISCO--ETC F/G 13/2
DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY. APPENDIX --ETC(U)
OCT 74 R SAMUELSON

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3 OF 5
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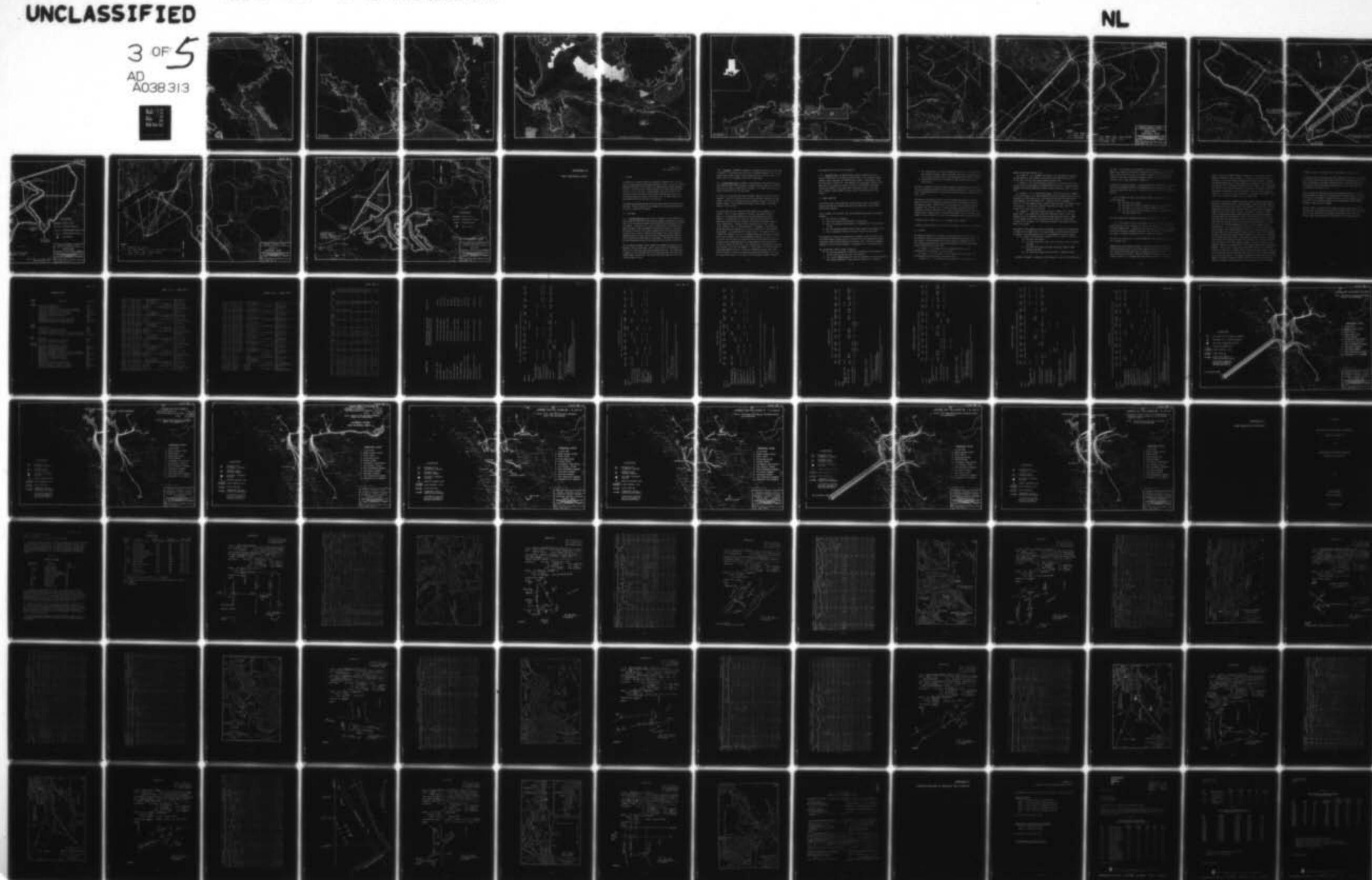

3 OF 5

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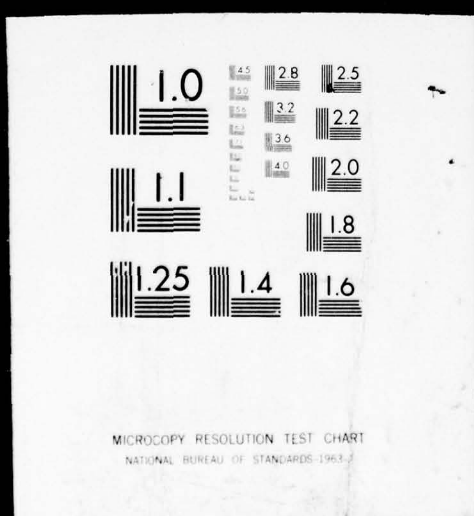
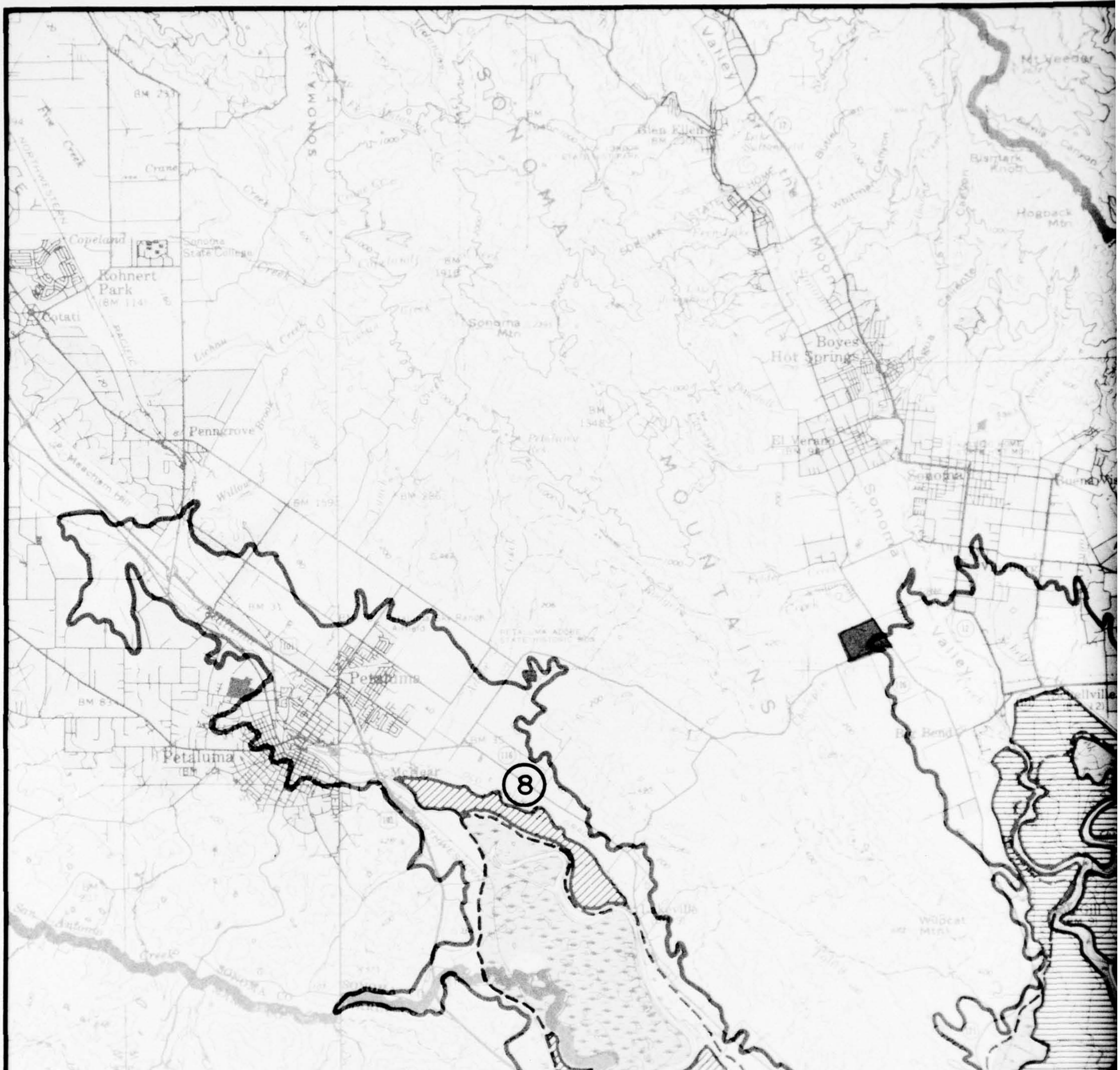
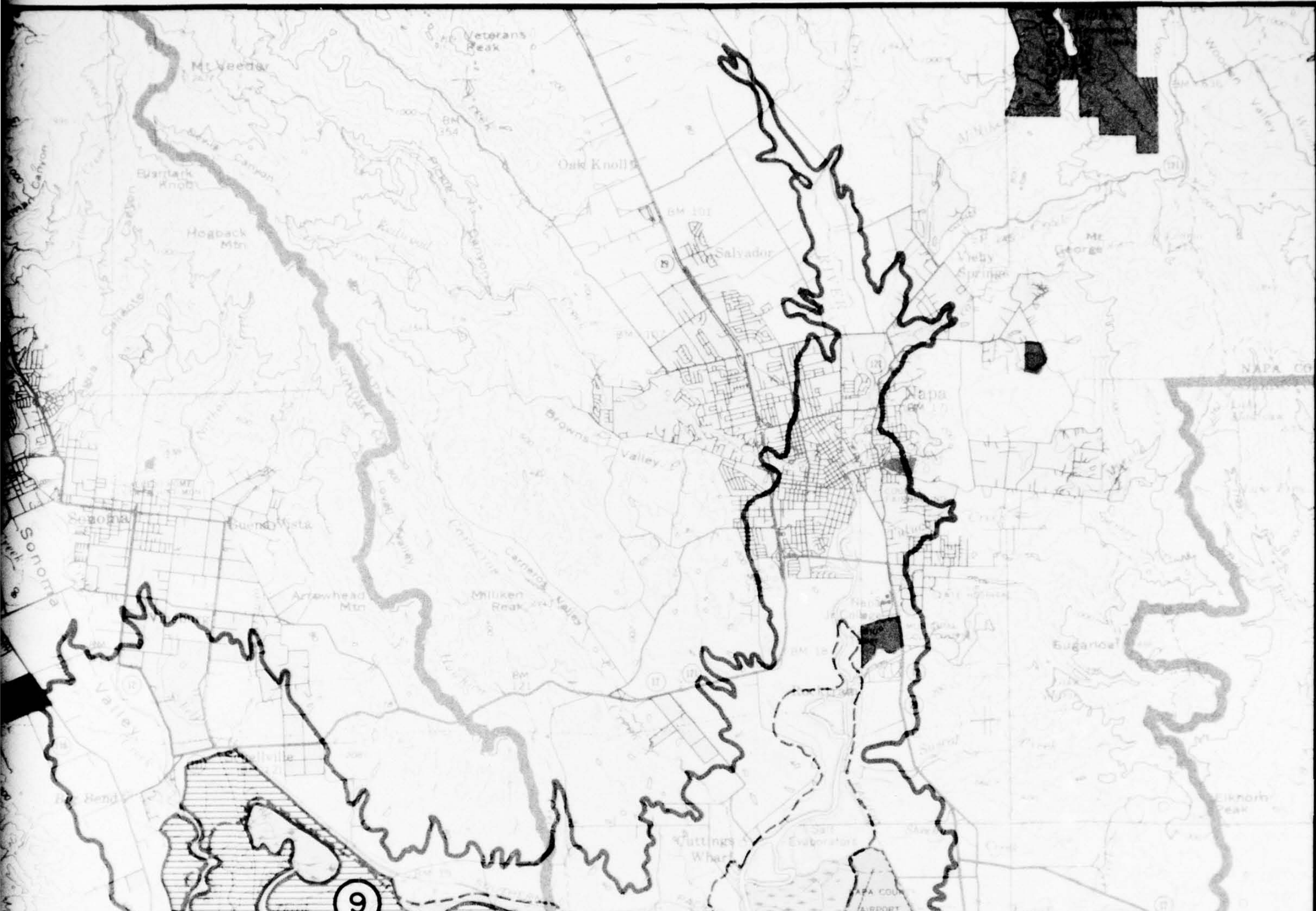



SONOMA CO.
SAN PABLO
BAY
SOLANO CO.
MARIN CO.
Vallejo
Rodeo
China Camp
Tank Farm
Sobrante
Richmond
WILDCAT CANYON REGIONAL PARK
SAN FRANCISCO
BAY
CONTRA COSTA CO.
Tiburon
Angel Island STATE PARK
Orinda


Rohnert Park
Cotati
Copeland
Sonoma State College
Penngrove
Petaluma
Glen Ellen
Boyes Hot Springs
El Verano
Sonoma
SONOMA MOUNTAINS
Sonoma Mtn
Mt Veeder
Hogback Mtn
Wildcat Mtn
Big Bend
8
8
8
9
FOR COLOR KEY
SEE PLATE VI - 3



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14
11
Potrero Hills
Bradmoor Island
MONTEZUMA
Morrow Island
GRIZZLY BAY
Garnet Point
Simmons Island
Wheeler Island
HONKER BAY
SUISUN
BAY
Preston Point
Benicia Bridge
Martinez
Mallard Res
Shore Acres
CONCORD NAVAL WEAPONS STATION
BUCHANAN FIELD
Pacheco
Concord
Mulligan Hill
Clayton
BRIONES REGIONAL PARK

FOR COLOR KEY SEE PLATE VI - 3

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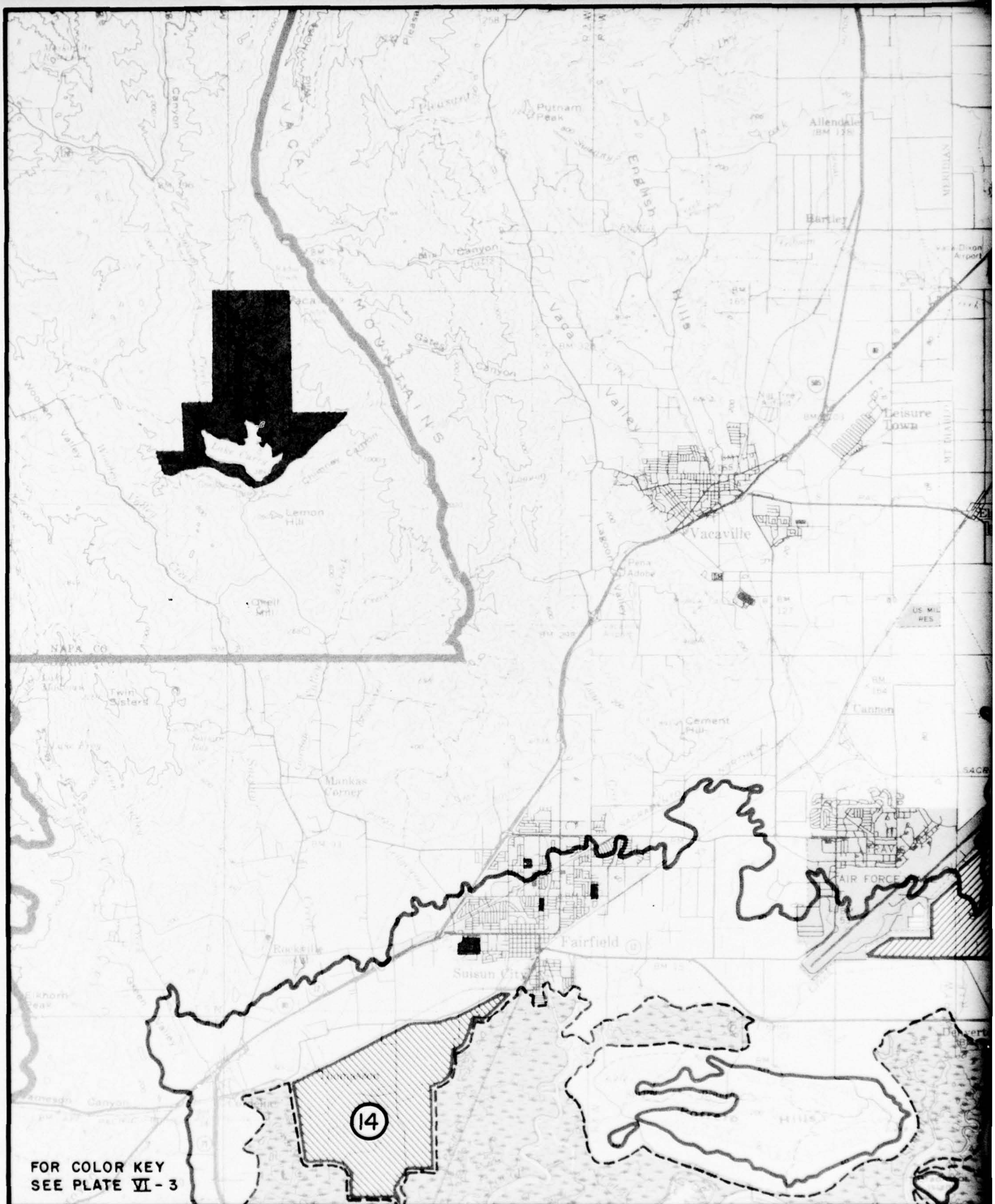
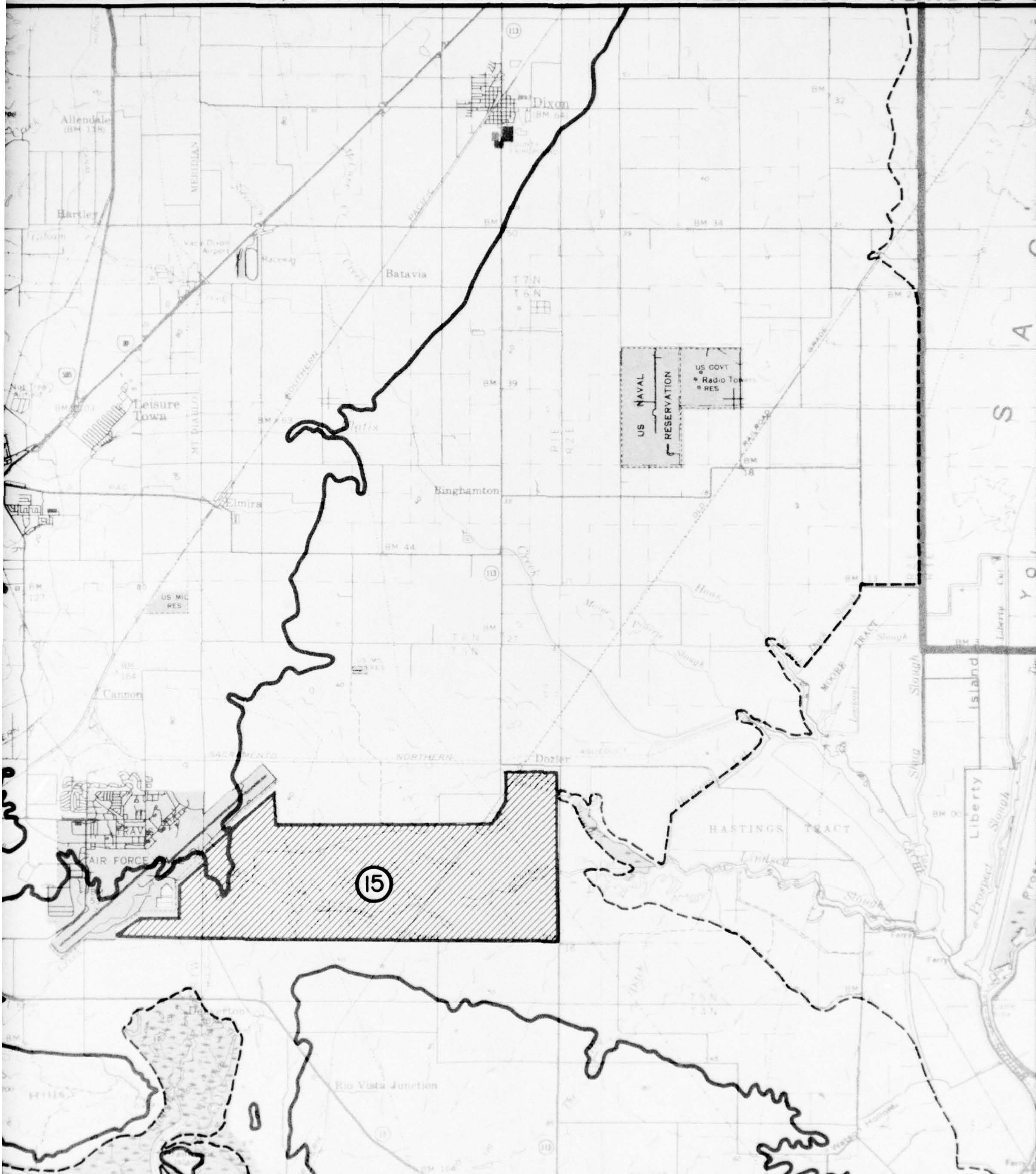

VACA MOUNTAINS
Putnam Peak
Allendale
English Hills
Vaca Valley
Leisure Town
Vacaville
Lemon Hill
NAPA CO
Twin Sisters
Mankas Corner
Cement Hill
Cannon
US MIL RES
AIR FORCE
Fairfield
Suisun City
Rockville
Elkhorn Peak
14
FOR COLOR KEY
SEE PLATE VI - 3



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IVER
LEVEE
APPROXIMATE
BDY
Reservoir
Donahue
Monte
Slough
Hog Island
Water Tank
Well
PRIVATE
LEVEE
Windmill
Windmill
Radio Towers
KCBS
Black John
Slough
SONOMA CO
MARIN CO
LEVEE
Creek
NOVATO
PETALUMA
SONOMA CO
MARIN CO
LEVEE

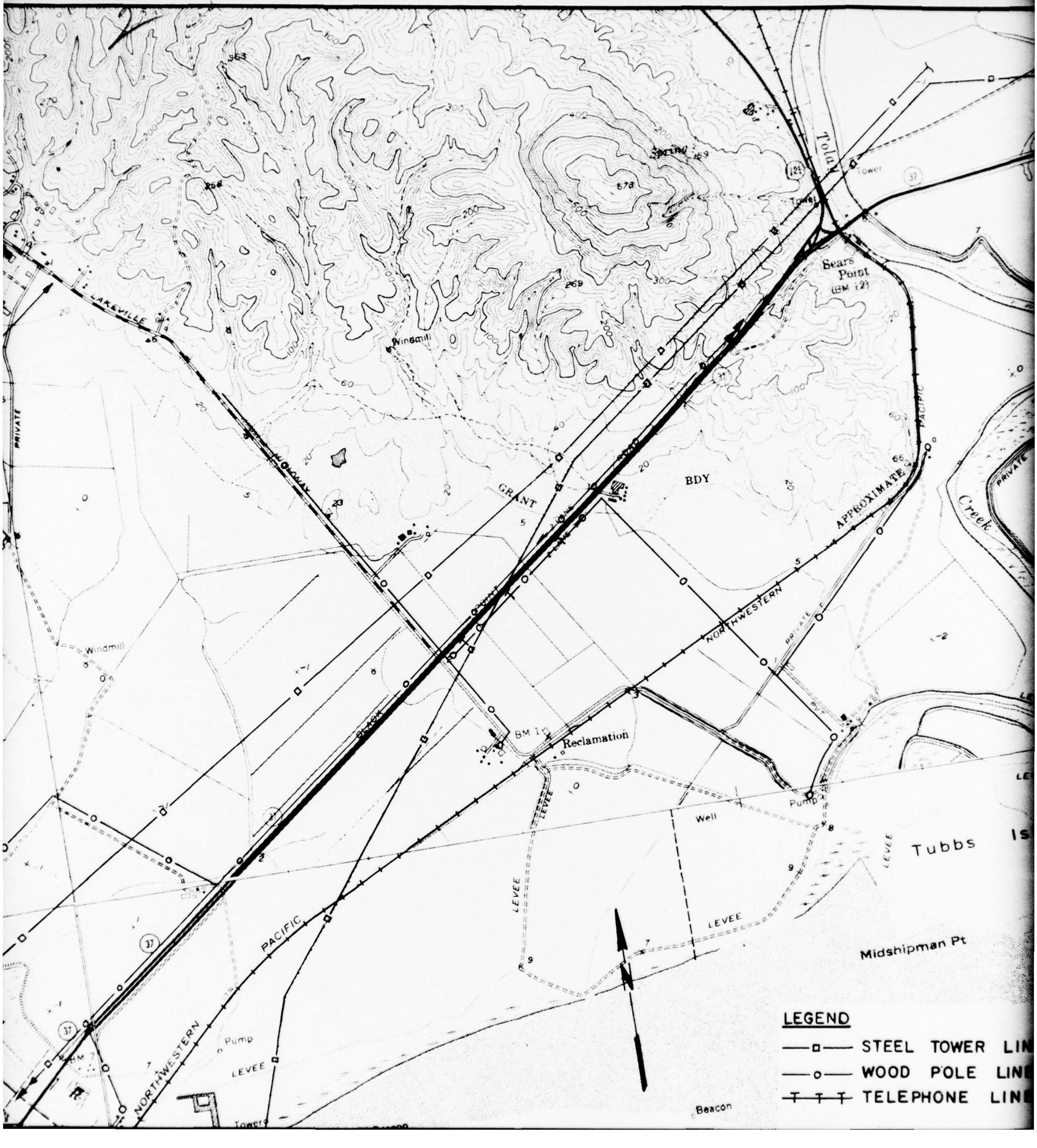
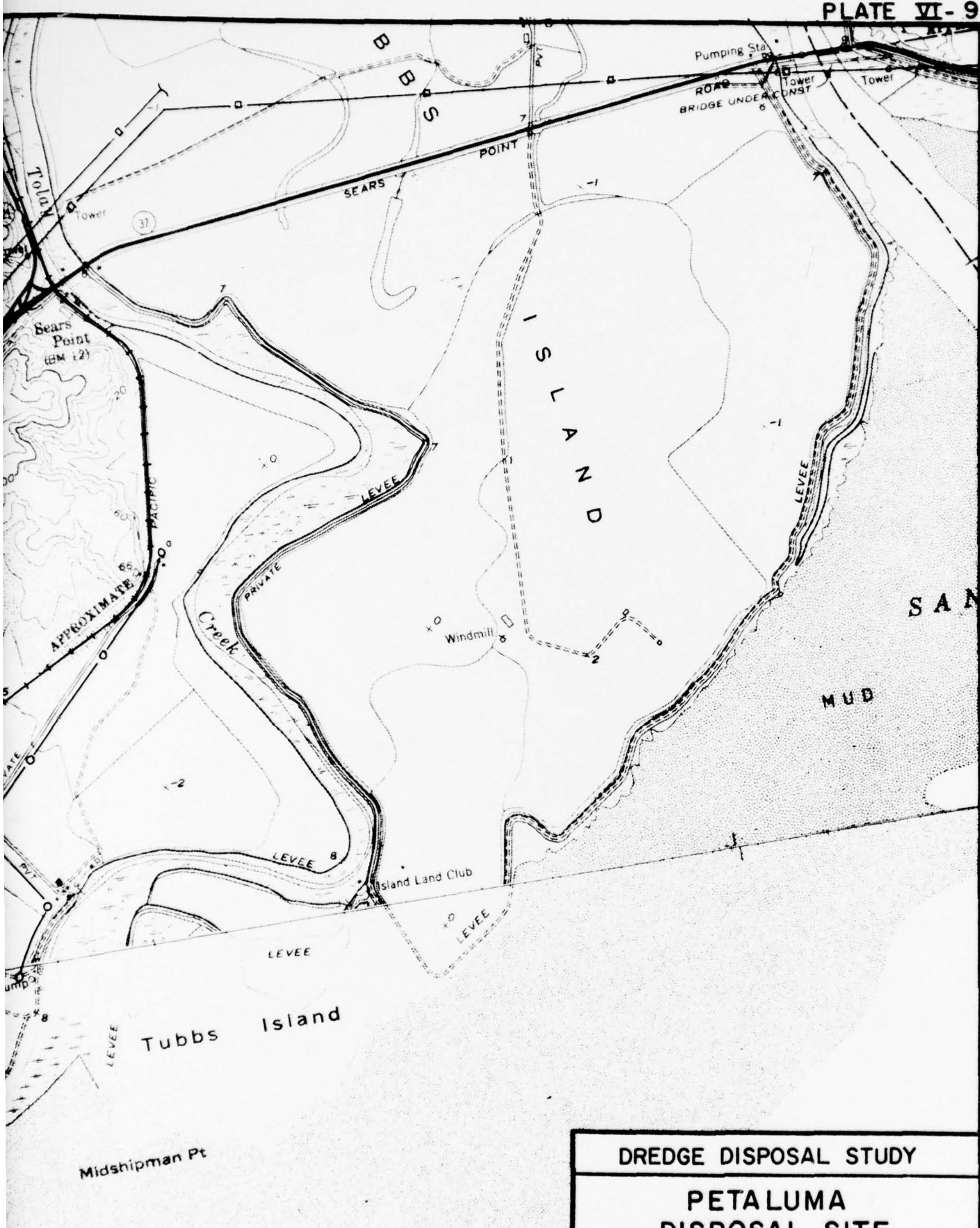

Tolay
Sears Point
(BM 12)
Tower
Windmill
LAKEVILLE
HIGHWAY
GRANT
BDY
APPROXIMATE
NORTHWESTERN
PACIFIC
PRIVATE
Creek
Reclamation
BM 1
Pump
Well
LEVEE
Tubbs
Midshipman Pt
Beacon
LEGEND
STEEL TOWER LIN
WOOD POLE LIN
TELEPHONE LIN

PLATE VI-9



DREDGE DISPOSAL STUDY

PETALUMA
DISPOSAL SITE

INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.

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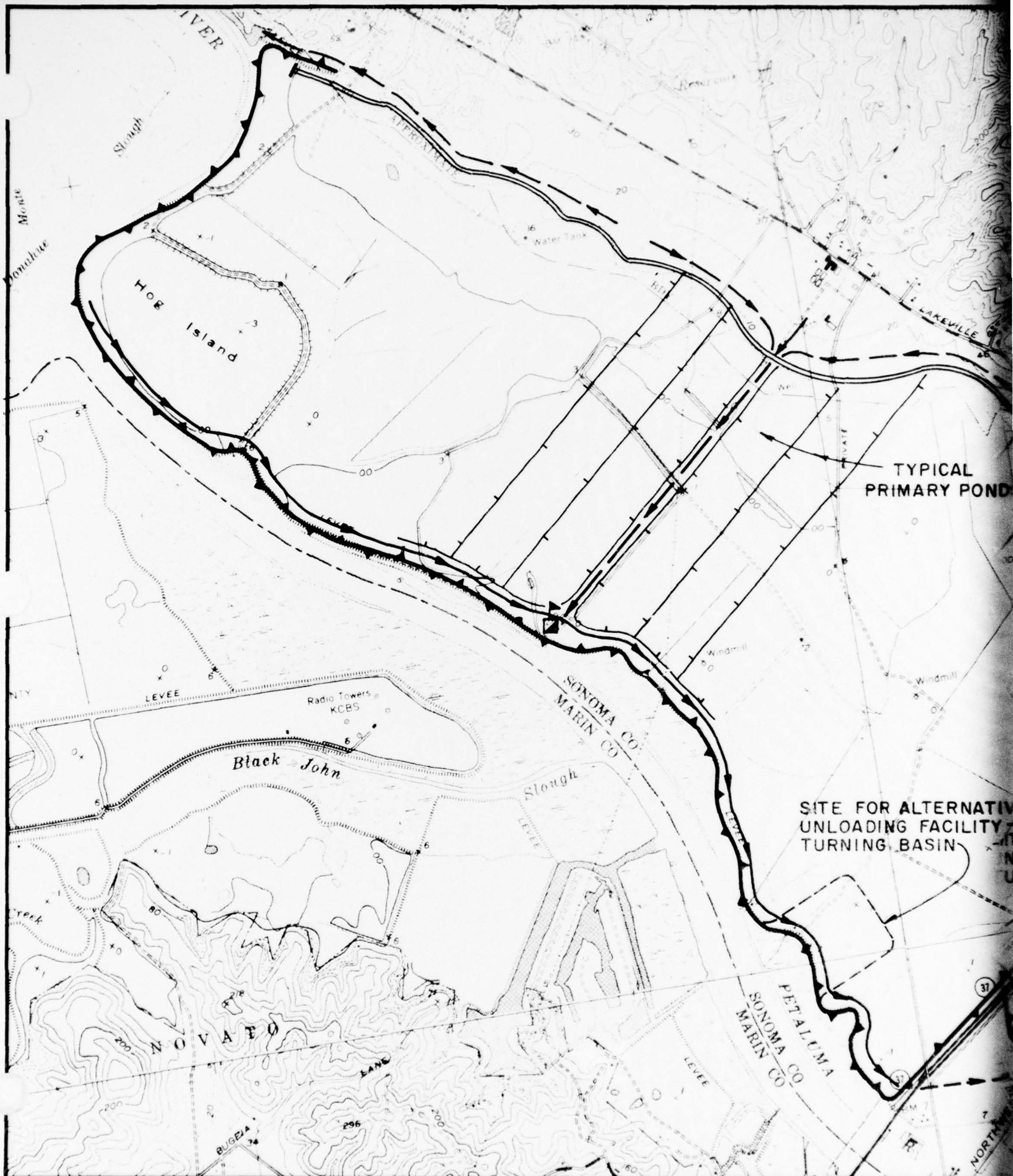
DATE: MAY 74		

EGEND

—□— STEEL TOWER LINES - HIGH VOLTAGE

—o— WOOD POLE LINES - 21 KV.

—T T— TELEPHONE LINE



IVER
Slough
Monte
Donahue
Hog Island
Water Tank
LAKEVILLE
TYPICAL
PRIMARY POND
LEVEE
Radio Towers
KCBS
Black John
Slough
SONOMA CO
MARIN CO
SITE FOR ALTERNATIV
UNLOADING FACILITY
TURNING BASIN
Windmill
Windmill
Creek
NOVATO
LANE
LEVEE
PETALUMA
SONOMA CO
MARIN CO

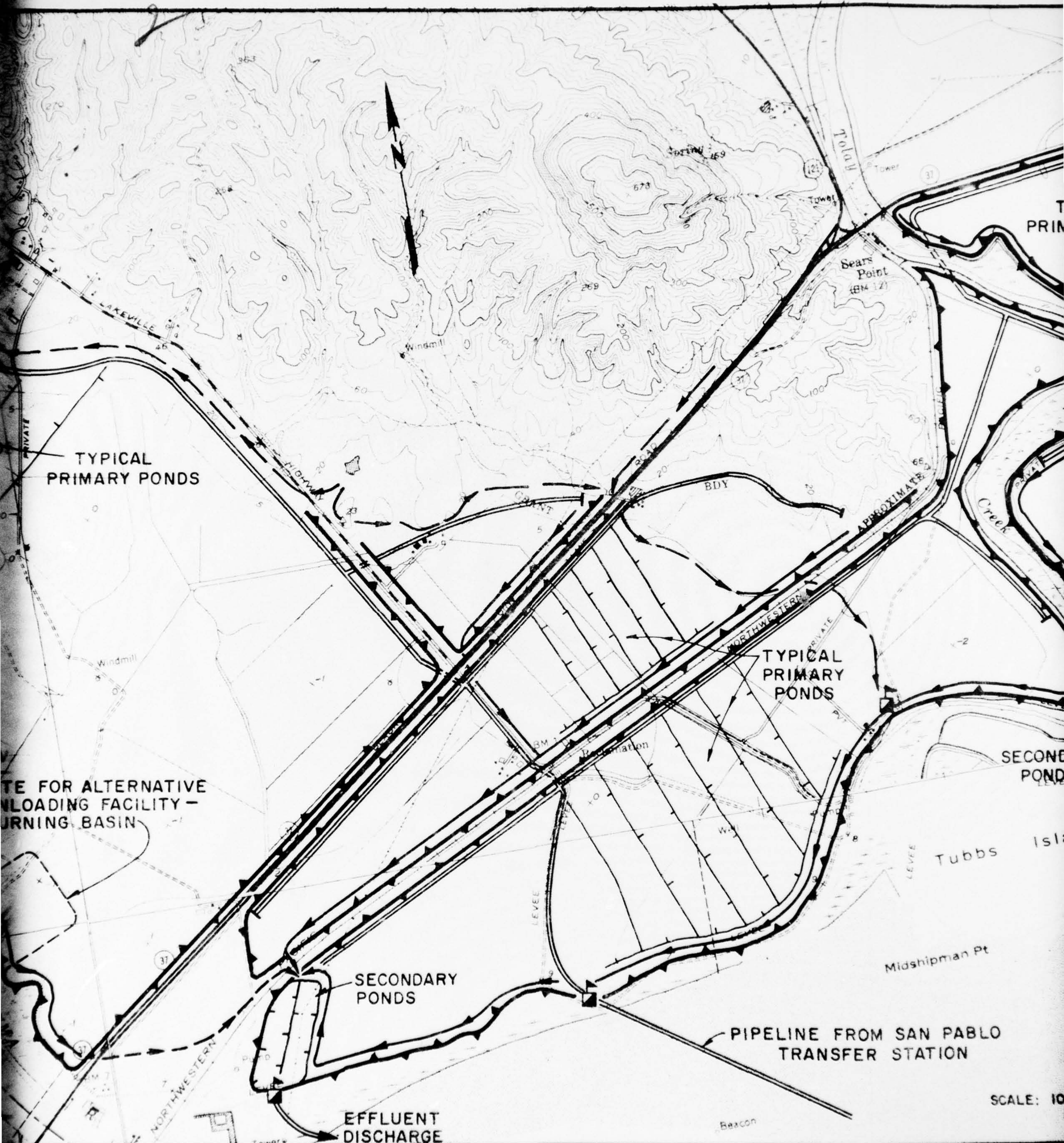
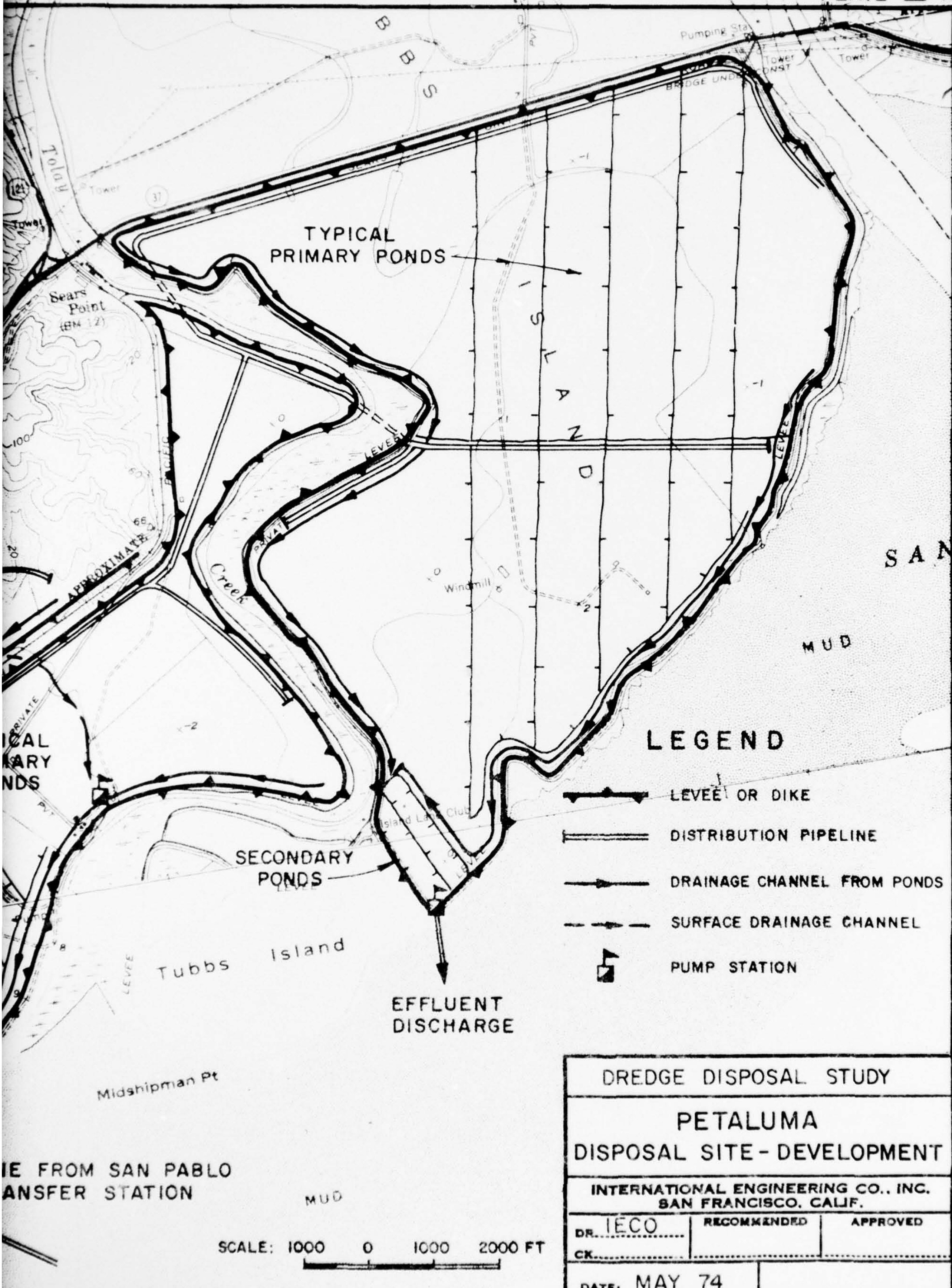

TYPICAL
PRIMARY PONDS
TYPICAL
PRIMARY
PONDS
TE FOR ALTERNATIVE
NLOADING FACILITY—
URNING BASIN
SECONDARY
PONDS
PIPELINE FROM SAN PABLO
TRANSFER STATION
EFFLUENT
DISCHARGE
SECOND
POND
T
PRIM
SCALE: IO
Sears Point
Tolay
Creek
Tubbs Isl
Midshipman Pt
LAKEVILLE
HIGHWAY
NORTHWESTERN
APPROXIMATE
BDY
Reclamation
LEVEE
Windmill
Tower
Beacon
N

PLATE VI-10



TYPICAL PRIMARY PONDS
Pumping Sta
Tower
Tolay
Sears Point
ISLAND
LEVEE
Creek
APPROXIMATE
Windmill
SAN
MUD
SECONDARY PONDS
Tubbs Island
EFFLUENT DISCHARGE
Midshipman Pt
IE FROM SAN PABLO
ANSFER STATION
MUD
LEGEND
LEVEE OR DIKE
DISTRIBUTION PIPELINE
DRAINAGE CHANNEL FROM PONDS
SURFACE DRAINAGE CHANNEL
PUMP STATION
SCALE: 1000 0 1000 2000 FT
DREDGE DISPOSAL STUDY
PETALUMA
DISPOSAL SITE - DEVELOPMENT
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
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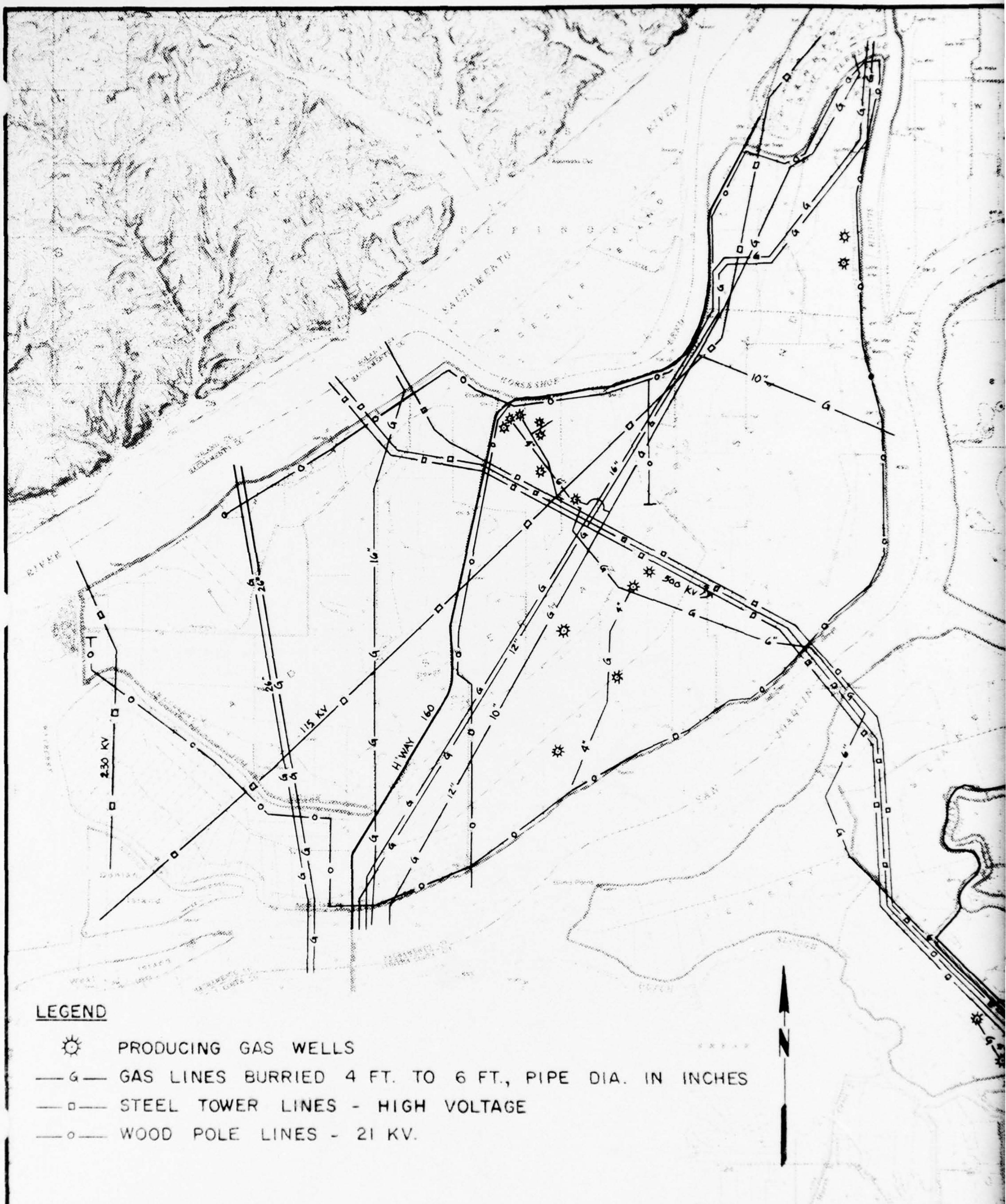
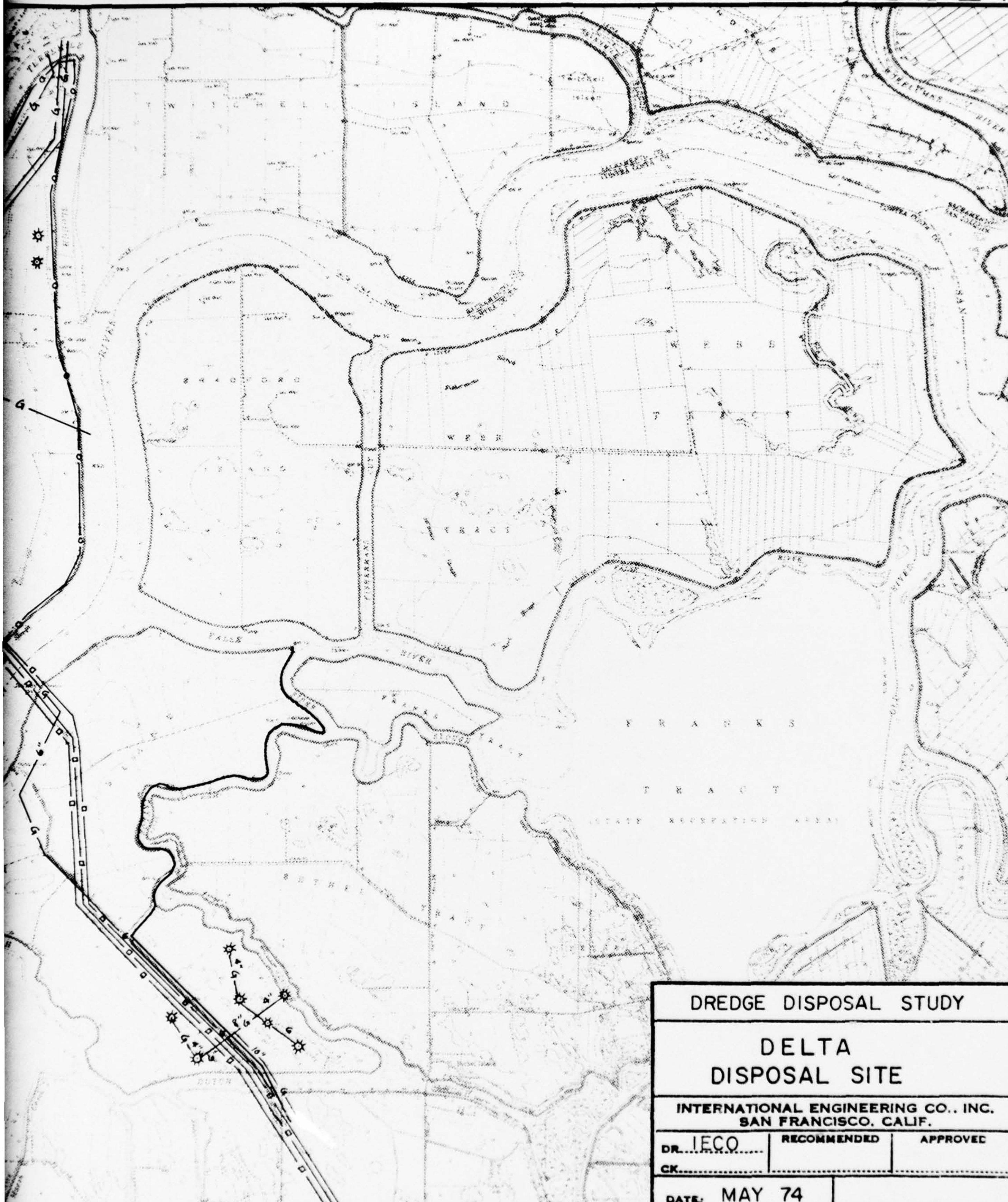


LEGEND
PRODUCING GAS WELLS
GAS LINES BURRIED 4 FT. TO 6 FT., PIPE DIA. IN INCHES
STEEL TOWER LINES - HIGH VOLTAGE
WOOD POLE LINES - 21 KV.
N
230 KV
115 KV
500 KV
H'WAY 160



DREDGE DISPOSAL STUDY

DELTA
DISPOSAL SITE

INTERNATIONAL ENGINEERING CO., INC.
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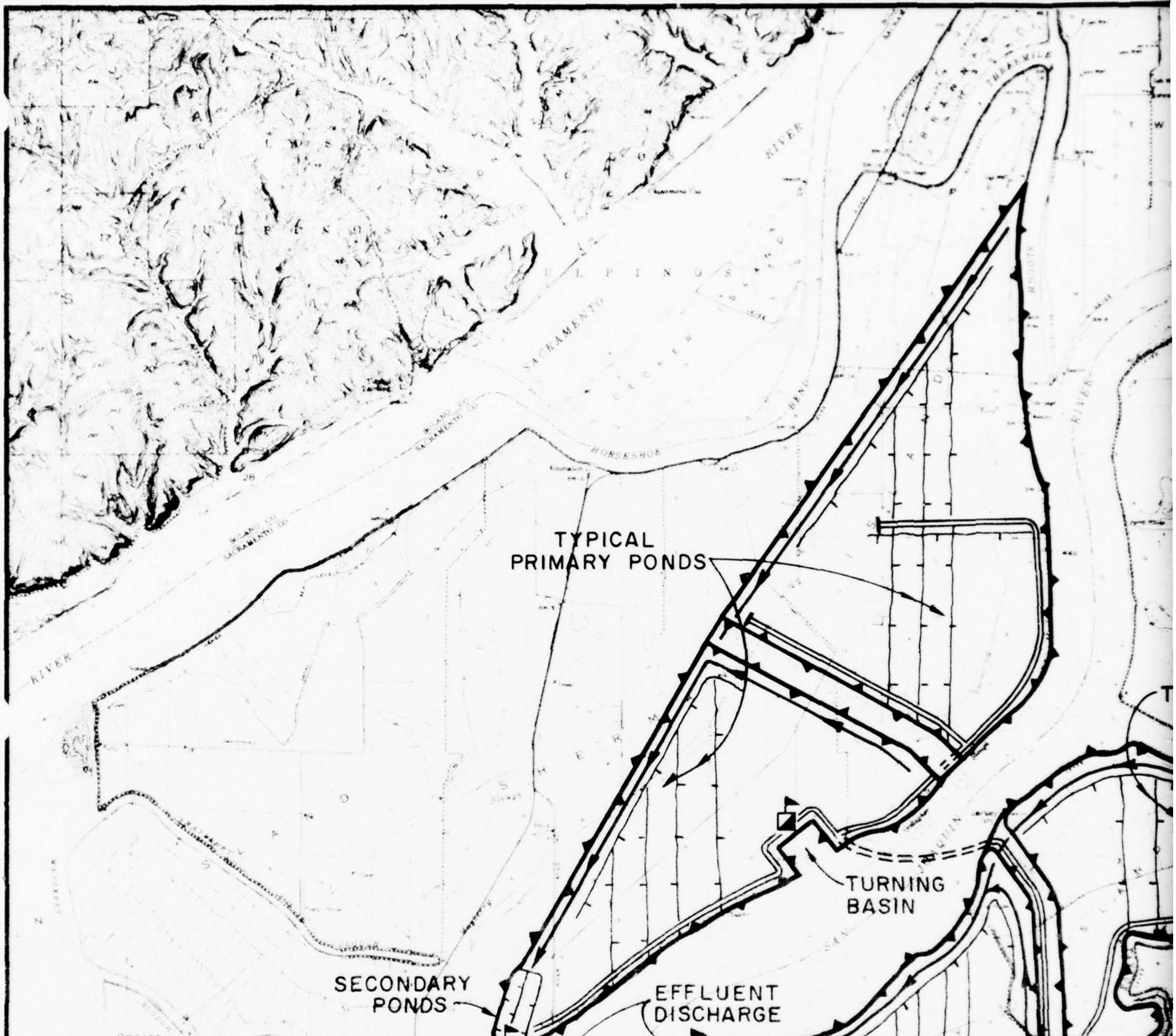
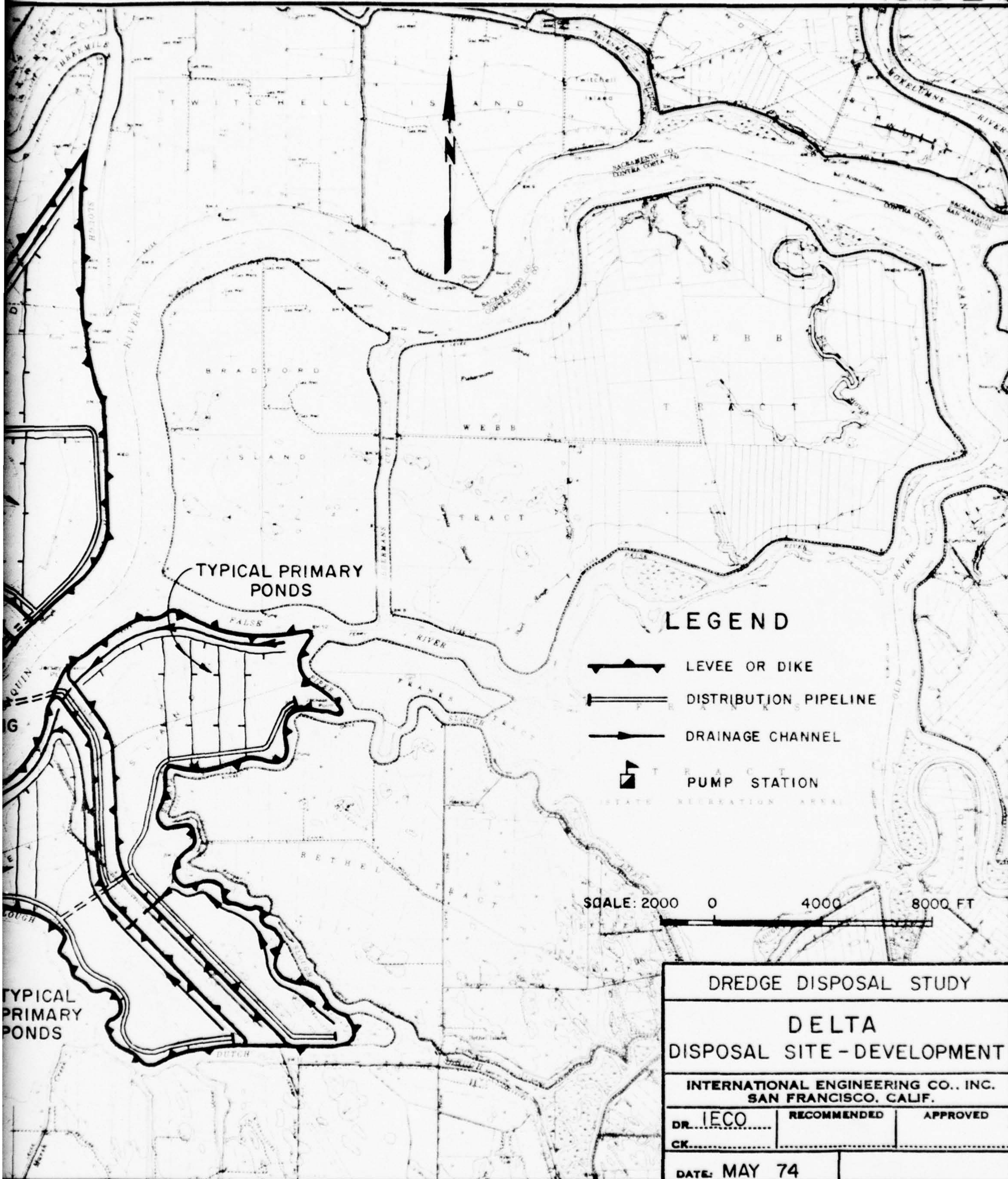


TYPICAL
PRIMARY PONDS
TURNING
BASIN
SECONDARY
PONDS
EFFLUENT
DISCHARGE
ALTERNATIVE TO
TURNING BASIN —
PIPELINE FROM SAN PABLO
TRANSFER STATION
SECONDARY
PONDS
TYPICAL
PRIMARY
PONDS


TWITCHELL ISLAND
Twitchell
N
SACRAMENTO CO.
CONTRA COSTA CO.
MOKELUMNE RIVER
SAN JOAQUIN
BRADFORD ISLAND
WEBB TRACT
WEBB
FALSE RIVER
FRANKS TRACT
STATE RECREATION AREA
BETHEL TRACT
OLD RIVER
DUTCH SLOUGH
TYPICAL PRIMARY PONDS
LEGEND
LEVEE OR DIKE
DISTRIBUTION PIPELINE
DRAINAGE CHANNEL
PUMP STATION
SCALE: 2000 0 4000 8000 FT
TYPICAL PRIMARY PONDS
DREDGE DISPOSAL STUDY
DELTA
DISPOSAL SITE - DEVELOPMENT
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO. CALIF.
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DATE: MAY 74

CHAPTER VII

COST COMPARISON MODEL

7.1 GENERAL

A mathematical simulation model was developed by Teknekron, Inc., of Berkeley to compare alternative dredging/transport systems. Using input data on dredging and disposal sites as well as on dredging and transport equipment, the model, with the aid of a digital computer, can rapidly compare various systems on a unit cost basis. Although model input used in this study reflects currently and potentially available dredging and disposal sites and dredging/transport systems, the flexibility of the model program will allow modifications and new input for future use.

The following paragraphs describe the input data used and the operation of the model. Finally, results of the computer run of the model are discussed and specific comparisons displayed.

7.2 DATA INPUT

7.2.1 <u>Site Characteristics</u>- Basic data for operation of the computer program include the locations of and distances between the dredging and disposal sites and the volumes and sequencing of dredging during the twenty-year period studied. In Chapters III, V, and VI respectively, the dredging sites, aquatic disposal sites, and potential land disposal sites are described. The centers of gravity of the twelve dredging sites and the seven aquatic disposal sites, as well as selected land disposal sites, were located on appropriate maps or charts, and the distances between them were measured along the most practicable routes and tabulated. The volumes of material from each dredging site used in the study are those listed in Table III-1.

For the computer program, it was assumed that dredging was occuring at all dredging sites during the year, which is not strictly in conformance with Table III-1, since some sites are not dredged every year. For comparison, a computer run was also made for the full 20-year period, 1975-1994, using volumes shown in Table III-1, and it was found that there was little significant change in costs.

7.2.2 Equipment - Dredging, transport, and transfer equipment was described in Chapter IV. Equipment characteristics, including dredging rates, tug and hopper dredge speeds, hopper dredge production rates and cycle times, and hourly costs of all equipment were used as input data.

7.2.3 System Combinations- Dredging, transportation, and transfer systems described previously were combined in several different ways to test for the least costly system or combination of systems. In a later section the economical alternatives will be described.

To assist in visualizing the various systems, Tables VII-1 and VII-2 were prepared. Table VII-1 briefly outlines the operational sequencing of each system. Table VII-2, extracted from the computer printout, lists the 108 systems studied. The information displayed in this table is described below for clarification.

In the columns after the method (system) number, the equipment is described: Clam (3 sizes), hydraulic (4 sizes), and hopper dredges (2 types -H-1, conventional bottom dump type, H-2, modified for direct pumpout). The notations "HI" and "LO" after the clam and hydraulic dredge descriptions indicate equipment of high and of average production rates, respectively. The next column indicates that a scow is used in the system, either S-1 (bottom dump) or S-2 (hopper). The following column describes the transfer unit, if used; numbered TU-1 through TU-10 (See Chapter IV for descriptions of these units). The symbols TEM 22 IN or TEM 28 IN indicate a 22" or 28" temporary pipeline, if used in a system, and FIX 28 indicates a 28" fixed (permanent) pipeline. The letters B, C, or D indicate the San Pablo Bay rehandling basin, the San Pablo Bay pipeline terminus, and a rehandling basin at a land disposal site, respectively. In the last column of Table VII-2, the disposal site is described, including restrictions on its use, for example, LT (less than) or GT (greater than) a prescribed number of miles (a function of pumping capacity) and "land except Petaluma" (listed as a constraint because the Petaluma site is not on a deep water channel, so a system involving pumpout through a transfer

unit anchored at the site is not feasible).

7.2.4 Disposal Sites - As noted earlier, aquatic disposal sites consist of fixed points in the Bay or offshore which can be reached by hopper dredges, scows, pipelines, or combinations of these. Land disposal sites were discussed in Chapter VI. The dredging sites and aquatic disposal sites specified in the Scope of Services, as well as the Petaluma and Sherman Island land disposal sites, were used in the model studies. The model will, however, accept changes to these sites if the need arises in the future.

7.3 MODEL OPERATION

Utilizing the data input described in the previous section, the computer program simulates and computes the least cost operations, using various optimization routines.

Given a dredge site, disposal site, and transportation system, the program computes:

- Time and cost of dredging
- Least cost tug and scow operation, if applicable
- Cost of installation and operation of temporary and fixed pipelines, if used
- Cost of transport methods based on time, volumes, and dredging rates
- Cost of operation of mobile and fixed transfer installations.

The program will analyze any combination of dredging sites, disposal sites, and transportation systems and will find the least cost dredging and transportation system for each dredging and disposal site. The entire dredging program for the Bay may be analyzed, or any parts of it, on a yearly basis.

The program does several things internally:

- The tug/scow operation is optimized to determine the combination of tug and scow to give the least cost operation.
- For a given dredging operation, based on equipment yearly availability, the program determines if more than one dredge unit is required.

- For systems that are shared by dredge sites, such as fixed pipelines and transfer stations, capital and annual costs are divided proportionally, based on dredge volumes for those dredge sites using the systems.
- Yearly mobilization costs are added to those systems that require mobilization.

The user can specify up to 200 different types of dredging systems and in one run he can change the number and types he wishes to consider. Also, for one run up to 18 dredge/disposal site schemes can be considered for any number of years from 1 to 20.

The program is designed to allow a user to modify practically all relevant features involved in determining comparative costs for different dredging and disposal systems. Specifically, it allows the user to define variables of dredge sites, disposal sites, transfer stations, tug/scow operations, temporary pipelines, fixed pipelines, types of dredging equipment, types of transfer units, dredge volumes, distances from dredge sites to disposal sites, number of hours equipment is available, and equipment hourly operational costs.

A sample printout (Table VII - 3) is included in this chapter.

A complete printout and user's manual are furnished as a separate transmittal.

7.4 RESULTS

The computer program can, of course, be used to generate cost data using any equipment system for any combination of dredging and disposal sites. For this study, it was determined that the most valuable information for future planning purposes would be gained by analysis of the following schemes, which are defined by disposal sites:

- Scheme I - It is assumed that all dredged material will be deposited at the 100 fathom line in the ocean.
- Scheme II - It is assumed in this instance that all material will be transported to the Petaluma land disposal site.
- Scheme III - It is assumed that all material will be taken to the

Sherman Island land disposal site.

- Scheme IV - It is assumed that there are no constraints on disposal and that material can be taken to the disposal site involving least cost. In all cases, this was the closest aquatic disposal site.

- Scheme V - The closest aquatic disposal site is also used, but with the restriction that movement of dredged material must be to seaward, in conformance with the San Francisco District's Public Notice No. 72-61 of 15 May, 1972.

- Scheme IV - It is assumed that RWQCB criteria, discussed in Chapter V, will be followed, i.e., that sediments polluted with organic material may be disposed of at the Alcatraz site, and sediments polluted with heavy metals may be dumped at the 100 fathom line. Disposal will be to seaward. In Table VII - 4, the dredging areas, sediment classifications, and disposal sites are displayed. The tentative sediment classifications were taken from Schedule "F" of the Scope of Services.

- Scheme VII - The same criteria as those in Scheme VI are followed except that it is assumed that regulations have been invoked prohibiting disposal at sea of sediments classified as containing heavy metals. Where the 100 fathom line was used for disposal under Scheme VI, land disposal is used in this instance. For illustrative purposes, the Petaluma land disposal site is used.

The results of the computer analyses for Schemes I through VII are summarized in Tables VII-5 through VII-11. For each scheme, several systems of disposal for material from each dredging site, with accompanying costs, are shown.

- For schemes involving aquatic disposal (I, IV, V, and VI), they are:
  - (A) The least cost system.
  - (B) The system involving least cost but which utilizes "available" equipment.
  - (C) The least cost system utilizing "available" hopper dredges (bottom dump type)
  - (D) The least cost system using "available" clamshell dredges.

"Available" equipment is defined as that presently in use in the San Francisco

Bay area. This excludes such equipment as hopper dredges with direct pumpout capability, clamshell and hydraulic dredges of high productivity which have been or could be built but are not presently operating in the Bay, fixed pipelines, pipelines discharging at aquatic disposal sites, and transfer stations such as those described in Chapter IV.

In addition, for these schemes a weighted average cost (determined by weighting unit costs of dredged material at the dredging sites in proportion to the volume of dredging at each site) is shown for the two most viable systems, (A) and (B).

- For schemes involving land disposal (Schemes II and III), the systems shown are:
  - (A) the least cost system
  - (E) the least cost system involving the use of a fixed pipeline
  - (F) the least cost system utilizing a temporary pipeline
  - (G) the least cost system involving the use of a turning basin at the land disposal site.

For these schemes the weighted average cost for system (A) is shown.

- For the scheme involving both aquatic and land disposal (Scheme VII), System (A)(least cost) is shown for all sites and systems (E), (F), and (G) for land disposal sites. Systems (E), (F), and (G) are the least cost systems using fixed pipelines, temporary pipelines, and turning basins, respectively. Here again, a weighted average unit cost is shown for system (A).

The least cost systems for all seven schemes are shown graphically on Plates VII-1 through VII-7.

Comparing the seven schemes analyzed, it can be seen that the least cost disposal method would be to the closest aquatic disposal site (Scheme IV), which would assume that there were no constraints on water disposal. The cost of disposing at aquatic sites but following the rule of disposing to seaward (Scheme V), is slightly more than that of Scheme IV. Disposal at

aquatic sites using RWQCB criteria (Scheme VI), is more costly than the above two schemes of aquatic disposal. Disposal at the 100 fathom line (Scheme I), is the most costly of the aquatic disposal schemes. Dredging and transportation costs to land disposal sites (Schemes II and III) are in the range of costs of disposal in accordance with RWQCB criteria (Scheme VI) but the cost of the overall operation is increased significantly when site development and operation costs are included. The same remarks apply to Scheme VII, in which the cost of disposing in accordance with RWQCB criteria, using a mix of land and aquatic sites, was determined.

The results of the cost comparison computer program indicate that the most economical dredging machine is a hopper dredge. Where the hopper dredge is constrained from working at certain sites because of shallow water, such as Petaluma River, Sonoma Creek, and Napa River, a large clamshell dredge was found to be the least costly. For very short hauls to aquatic disposal sites, the bottom dump hopper dredge was found to be the least expensive transport mode; for longer hauls, where a fixed pipeline was included in the system (to the land disposal sites or to the 100 fathom line), it was found that the pipeline was the most economical transport mode. For other long hauls, the tug-scow combination proved to be the cheapest mode of transportation. In the most economical systems, the scow was filled by direct pumpout from a hopper dredge or directly by a large clamshell dredge. As noted above, the large clamshell dredges (18 and 13 cubic yard capacity) proved to be least costly when a hopper dredge was not feasible. In system (A) described previously, where "non-available" equipment could be used, the high productivity (denoted as "modified") clamshell was invariably found to have the lowest cost of the clamshell dredges. Hydraulic dredges did not generally appear to be competitive with the hopper dredges and large clamshell dredges. This was due in large part to the high capital cost of temporary pipelines of more than a minimum length leading from these dredges, since the cost of the pipeline could only be spread over the volume of material pumped for one specific project. The hydraulic dredge costs approached those of the hopper or clamshell dredges at dredge disposal locations involving short temporary pipelines such as Mare Island to Carquinez, San Francisco Harbor

to Hunter's Point, or Petaluma River to Petaluma land disposal site.

It should be borne in mind that the costs tabulated in Tables VII-5 through VII-11 do not include the contractor's mark-up for overhead and profit or the Corps' percentage for overhead, supervision, etc. These additional costs are subject to many variations, but generally will be in the range of 25 to 30 percent of the basic cost.

Also, the costs were based on analyses of dredging operations in which estimated production rates were in turn based on available records. The costs are sensitive to changes in production rates, and could change greatly if, as a result of more detailed studies of both Government and contractors' equipment, these rates are changed.

The costs shown in connection with schemes involving land disposal sites include costs of developing and operating the appropriate land site. These costs are for acquisition, development, and operation only, and do not include additional processing or conditioning of the dredged material.

TABLE VII - 1

DISPOSAL SYSTEMS

Dredging Equipment	Transport System	Disposal Site
Clamshell (3 sizes)	Transfer Barge and Temporary Pipeline	Aquatic
"	Transfer Barge and Temporary Pipeline	Land
"	Transfer Barge, Temporary Pipeline, San Pablo Bay Terminus, Fixed Pipeline	Land
"	Transfer Barge, Temporary Pipeline, San Pablo Bay Terminus, Fixed Pipeline	100 Fathom Line
"	Bottom Dump Scow, San Pablo Bay Dump Basin, Fixed Pipeline	Land
"	Bottom Dump Scow, San Pablo Bay Dump Basin, Fixed Pipeline	100 Fathom Line
"	Bottom Dump Scow, Dump Basin at Land Disposal Site	Land
"	Bottom Dump Scow	Aquatic
"	Scow Without Bottom Dump, San Pablo Bay Terminus, Fixed Pipeline	Land
"	Scow Without Bottom Dump, San Pablo Bay Terminus, Fixed Pipeline	100 Fathom Line
"	Scow Without Bottom Dump, Transfer Barge at Land Disposal Site	Land
Hydraulic Dredge (4 sizes)	Temporary Pipeline	Aquatic
"	Temp. Pipeline, Transfer Barge, Temporary Pipeline	Land
"	Temp. Pipeline, Transfer Barge, Temporary Pipeline	Aquatic
"	Temp. Pipeline, Transfer Barge, Temp. Pipeline, S.P. Bay Terminus, Fixed Pipeline	Land
"	Temp. Pipeline, Transfer Barge, Temp. Pipeline, S.P. Bay Terminus, Fixed Pipeline	100 Fathom Line
Hopper Dredge	Hopper Dredge	Aquatic
"	Hopper Dredge, San Pablo Bay Dump Basin, Fixed Pipeline	Land
"	Hopper Dredge, Transfer Barge at Land Disposal Site	Land
Hopper Dredge with pumpout	Hopper Dredge, San Pablo Bay Terminus, Fixed Pipeline	Land
"	Hopper Dredge, San Pablo Bay Terminus, Fixed Pipeline	100 Fathom Line
"	Hopper Dredge, Transfer Barge, Temporary Pipeline	Aquatic
"	Hopper Dredge, Transfer Barge, Temporary Pipeline	Land
"	Hopper Dredge, Transfer Barge, Temp. Pipeline, S.P. Bay Terminus, Fixed Pipeline	Land
"	Hopper Dredge, Transfer Barge, Temp. Pipeline, S.P. Bay Terminus, Fixed Pipeline	100 Fathom Line
"	Hopper Dredge, Transfer Barge at Land Disposal Site	Land
"	Bottom Dump Scow, S.P. Bay Dump Basin, Fixed Pipeline	Land
"	Bottom Dump Scow, S.P. Bay Dump Basin, Fixed Pipeline	100 Fathom Line
"	Bottom Dump Scow	Aquatic
"	Bottom Dump Scow, Transfer Barge at Land Disposal Site	Land
"	Scow Without Bottom Dump, S.P. Bay Terminus, Fixed Pipeline	Land
"	Scow Without Bottom Dump, S.P. Bay Terminus, Fixed Pipeline	100 Fathom Line
"	Scow Without Bottom Dump, Transfer Barge at Land Disposal Site	Land

METHOD	1 =	CLAM 9CY LO		,TU6	,TEM,22 IN	,	,		,WATER .LT. 8
METHOD	2 =	CLAM 9CY LO		,TU8	,TEM,22 IN	,	,		,WATER .GT. 8
METHOD	3 =	CLAM 9CY LO		,TU8	,TEM,22 IN	,	,		,LAND
METHOD	4 =	CLAM 9CY LO		,TU8	,TEM,22 IN	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	5 =	CLAM 9CY LO	S1	,TU9	,	, B	,FIX,28 IN		,100 FATH, LAND
METHOD	6 =	CLAM 9CY LO	S1	,TU1	,	, D	,		,LAND
METHOD	7 =	CLAM 9CY LO	S2	,TU9	,	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	8 =	CLAM 9CY LO	S2	,TU1	,	,	,		,LAND EXCEPT PETALUMA
METHOD	9 =	CLAM 9CY LO	S1	,	,	,	,		,WATER ANY
METHOD	10 =	CLAM 9CY HI		,TU6	,TEM,22 IN	,	,		,WATER .LT. 8
METHOD	11 =	CLAM 9CY HI		,TU8	,TEM,22 IN	,	,		,WATER .GT. 8
METHOD	12 =	CLAM 9CY HI		,TU8	,TEM,22 IN	,	,		,LAND
METHOD	13 =	CLAM 9CY HI		,TU8	,TEM,22 IN	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	14 =	CLAM 9CY HI	S1	,TU9	,	, B	,FIX,28 IN		,100 FATH, LAND
METHOD	15 =	CLAM 9CY HI	S1	,TU1	,	, D	,		,LAND
METHOD	16 =	CLAM 9CY HI	S2	,TU9	,	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	17 =	CLAM 9CY HI	S2	,TU1	,	,	,		,LAND EXCEPT PETALUMA
METHOD	18 =	CLAM 9CY HI	S1	,	,	,	,		,WATER ANY
METHOD	19 =	CLAM 13CY LO		,TU6	,TEM,22 IN	,	,		,WATER .LT. 8
METHOD	20 =	CLAM 13CY LO		,TU8	,TEM,22 IN	,	,		,WATER .GT. 8
METHOD	21 =	CLAM 13CY LO		,TU8	,TEM,22 IN	,	,		,LAND
METHOD	22 =	CLAM 13CY LO		,TU8	,TEM,22 IN	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	23 =	CLAM 13CY LO	S1	,TU9	,	, B	,FIX,28 IN		,100 FATH, LAND
METHOD	24 =	CLAM 13CY LO	S1	,TU1	,	, D	,		,LAND
METHOD	25 =	CLAM 13CY LO	S2	,TU9	,	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	26 =	CLAM 13CY LO	S2	,TU1	,	,	,		,LAND EXCEPT PETALUMA
METHOD	27 =	CLAM 13CY LO	S1	,	,	,	,		,WATER ANY
METHOD	28 =	CLAM 13CY HI		,TU6	,TEM,22 IN	,	,		,WATER .LT. 8
METHOD	29 =	CLAM 13CY HI		,TU8	,TEM,22 IN	,	,		,WATER .GT. 8
METHOD	30 =	CLAM 13CY HI		,TU8	,TEM,22 IN	,	,		,LAND
METHOD	31 =	CLAM 13CY HI		,TU8	,TEM,22 IN	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	32 =	CLAM 13CY HI	S1	,TU9	,	, B	,FIX,28 IN		,100 FATH, LAND
METHOD	33 =	CLAM 13CY HI	S1	,TU1	,	, D	,		,LAND
METHOD	34 =	CLAM 13CY HI	S2	,TU9	,	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	35 =	CLAM 13CY HI	S2	,TU1	,	,	,		,LAND EXCEPT PETALUMA
METHOD	36 =	CLAM 13CY HI	S1	,	,	,	,		,WATER ANY
METHOD	37 =	CLAM 18CY LO		,TU6	,TEM,22 IN	,	,		,WATER .LT. 8
METHOD	38 =	CLAM 18CY LO		,TU8	,TEM,22 IN	,	,		,WATER .GT. 8
METHOD	39 =	CLAM 18CY LO		,TU8	,TEM,22 IN	,	,		,LAND
METHOD	40 =	CLAM 18CY LO		,TU8	,TEM,22 IN	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	41 =	CLAM 18CY LO	S1	,TU9	,	, B	,FIX,28 IN		,100 FATH, LAND
METHOD	42 =	CLAM 18CY LO	S1	,TU1	,	, D	,		,LAND
METHOD	43 =	CLAM 18CY LO	S2	,TU9	,	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	44 =	CLAM 18CY LO	S2	,TU1	,	,	,		,LAND EXCEPT PETALUMA
METHOD	45 =	CLAM 18CY LO	S1	,	,	,	,		,WATER ANY
METHOD	46 =	CLAM 18CY HI		,TU6	,TEM,22 IN	,	,		,WATER .LT. 8
METHOD	47 =	CLAM 18CY HI		,TU8	,TEM,22 IN	,	,		,WATER .GT. 9
METHOD	48 =	CLAM 18CY HI		,TU8	,TEM,22 IN	,	,		,LAND
METHOD	49 =	CLAM 18CY HI		,TU8	,TEM,22 IN	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	50 =	CLAM 18CY HI	S1	,TU9	,	, B	,FIX,28 IN		,100 FATH, LAND
METHOD	51 =	CLAM 18CY HI	S1	,TU1	,	, D	,		,LAND
METHOD	52 =	CLAM 18CY HI	S2	,TU9	,	, C	,FIX,28 IN		,100 FATH, LAND
METHOD	53 =	CLAM 18CY HI	S2	,TU1	,	,	,		,LAND EXCEPT PETALUMA
METHOD	54 =	CLAM 18CY HI	S1	,	,	,	,		,WATER ANY
METHOD	55 =	HYD 16 IN LO		,	,	,	,		,WATER .LT. 3

Sheet 2 of 2 TABLE VII - 2

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METHOD  56 = HYD 16 IN LO       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  57 = HYD 16 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  58 = HYD 16 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  59 = HYD 16 IN LO       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  60 = HYD 16 IN HI       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  61 = HYD 16 IN HI       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  62 = HYD 16 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  63 = HYD 16 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  64 = HYD 16 IN HI       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  65 = HYD 24 IN LO       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  66 = HYD 24 IN LO       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  67 = HYD 24 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  68 = HYD 24 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  69 = HYD 24 IN LO       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  70 = HYD 24 IN HI       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  71 = HYD 24 IN HI       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  72 = HYD 24 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  73 = HYD 24 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  74 = HYD 24 IN HI       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  75 = HYD 30 IN LO       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  76 = HYD 30 IN LO       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  77 = HYD 30 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  78 = HYD 30 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  79 = HYD 30 IN LO       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  80 = HYD 30 IN HI       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  81 = HYD 30 IN HI       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  82 = HYD 30 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  83 = HYD 30 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  84 = HYD 30 IN HI       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  85 = HYD 36 IN LO       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  86 = HYD 36 IN LO       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  87 = HYD 36 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  88 = HYD 36 IN LO       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  89 = HYD 36 IN LO       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  90 = HYD 36 IN HI       ,    ,           ,   ,             ,WATER .LT. 3
METHOD  91 = HYD 36 IN HI       ,TU5 ,TEM,22 IN  ,   ,             ,WATER .LT. 8
METHOD  92 = HYD 36 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,LAND
METHOD  93 = HYD 36 IN HI       ,TU7 ,TEM,22 IN  ,   ,             ,WATER .GT. 8
METHOD  94 = HYD 36 IN HI       ,TU7 ,TEM,22 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  95 = HOPPER 1           ,    ,           ,   ,             ,WATER ANY
METHOD  96 = HOPPER 1           ,TU9 ,           , B ,FIX,28 IN    ,LAND
METHOD  97 = HOPPER 1           ,TU1 ,           , D ,             ,LAND
METHOD  98 = HOPPER 2           ,TU10,           , C ,FIX,28 IN    ,100 FATH, LAND
METHOD  99 = HOPPER 2           ,TU3 ,TEM,28 IN  ,   ,             ,WATER .LT. 9
METHOD 100 = HOPPER 2           ,TU4 ,TEM,28 IN  ,   ,             ,WATER .GT. 9
METHOD 101 = HOPPER 2           ,TU4 ,TEM,28 IN  ,   ,             ,LAND
METHOD 102 = HOPPER 2           ,TU4 ,TEM,28 IN  , C ,FIX,28 IN    ,100 FATH, LAND
METHOD 103 = HOPPER 2           ,TU2 ,           ,   ,             ,LAND EXCEPT PETALUMA
METHOD 104 = HOPPER 2        S1 ,TU9 ,           , B ,FIX,28 IN    ,100 FATH, LAND
METHOD 105 = HOPPER 2        S1 ,    ,           ,   ,             ,WATER ANY
METHOD 106 = HOPPER 2        S1 ,TU1 ,           , D ,             ,LAND
METHOD 107 = HOPPER 2        S2 ,TU9 ,           , C ,FIX,28 IN    ,100 FATH, LAND
METHOD 108 = HOPPER 2        S2 ,TU1 ,           ,   ,             ,LAND EXCEPT PETALUMA
```

TABLE VII - 3

SCHEME 1 CLOSED

DREDGE SITE = MARE ISLAND DISPOSAL SITE = CARQUINEZ DREDGE VOL = 3050000. DISTANCE 3. TRAN. PT. 0. YEAR 1975

DREDGING EQUIPMENT	(TYPE,NO) TUG SCOW	TRAN UNIT	DREDGING	TRANSFER UNIT	TEMPORARY PIPELINE	FIXED PIPELINE	STATION TRANSFER	TUG/SCOW	TOTAL COST	SYSTEM NUMBER
CLAM 9CY LO	(0, 0)-(0, 0)	TU6	.836	.330	.104	0.	0.	0.	1.269	1 (2)
CLAM 9CY LO	(1, 1)-(1, 3)		.836	0.	0.	0.	0.	.851	1.687	9 (2)
CLAM 9CY HI	(0, 0)-(0, 0)	TU6	.731	.279	.925E-01	0.	0.	0.	1.103	10 (2)
CLAM 9CY HI	(1, 1)-(1, 3)		.731	0.	0.	0.	0.	.707	1.438	18 (2)
CLAM 13CY LO	(0, 0)-(0, 0)	TU5	.661	.237	.833E-01	0.	0.	0.	.981	19 (2)
CLAM 13CY LO	(1, 1)-(1, 3)		.661	0.	0.	0.	0.	.588	1.250	27 (2)
CLAM 13CY HI	(0, 0)-(0, 0)	TU6	.472	.169	.682E-01	0.	0.	0.	.709	28 (1)
CLAM 13CY HI	(1, 1)-(1, 2)		.472	0.	0.	0.	0.	.328	.800	36 (1)
CLAM 18CY LO	(0, 0)-(0, 0)	TU6	.543	.180	.707E-01	0.	0.	0.	.793	37 (1)
CLAM 18CY LO	(1, 1)-(1, 2)		.543	0.	0.	0.	0.	.355	.897	45 (1)
CLAM 18CY HI	(0, 0)-(0, 0)	TU6	.439	.156	.653E-01	0.	0.	0.	.710	46 (1)
CLAM 18CY HI	(1, 1)-(1, 2)		.439	0.	0.	0.	0.	.297	.787	54 (1)
HYD 16 IN LO	(0, 0)-(0, 0)		.530	0.	0.	0.	0.	0.	.530	55 (2)
HYD 16 IN LO	(0, 0)-(0, 0)	TU5	.530	.189	.808E-01	0.	0.	0.	.800	56 (2)
HYD 16 IN HI	(0, 0)-(0, 0)		.438	0.	0.	0.	0.	0.	.438	60 (2)
HYD 16 IN HI	(0, 0)-(0, 0)	TU5	.438	.156	.721E-01	0.	0.	0.	.666	61 (2)
HYD 24 IN LO	(0, 0)-(0, 0)		.639	0.	0.	0.	0.	0.	.639	65 (1)
HYD 24 IN LO	(0, 0)-(0, 0)	TU5	.639	.139	.673E-01	0.	0.	0.	.845	66 (1)
HYD 24 IN HI	(0, 0)-(0, 0)		.425	0.	0.	0.	0.	0.	.425	70 (1)
HYD 24 IN HI	(0, 0)-(0, 0)	TU5	.425	.974E-01	.562E-01	0.	0.	0.	.579	71 (1)
HYD 30 IN LO	(0, 0)-(0, 0)		.612	0.	0.	0.	0.	0.	.612	75 (1)
HYD 30 IN LO	(0, 0)-(0, 0)	TU5	.612	.111	.598E-01	0.	0.	0.	.782	76 (1)
HYD 30 IN HI	(0, 0)-(0, 0)		.409	0.	0.	0.	0.	0.	.409	80 (1)
HYD 30 IN HI	(0, 0)-(0, 0)	TU5	.409	.795E-01	.514E-01	0.	0.	0.	.540	81 (1)
HYD 36 IN LO	(0, 0)-(0, 0)		.571	0.	0.	0.	0.	0.	.571	85 (1)
HYD 36 IN LO	(0, 0)-(0, 0)	TU5	.571	.974E-01	.562E-01	0.	0.	0.	.724	86 (1)
HYD 36 IN HI	(0, 0)-(0, 0)		.384	0.	0.	0.	0.	0.	.384	90 (1)
HYD 36 IN HI	(0, 0)-(0, 0)	TU5	.384	.713E-01	.491E-01	0.	0.	0.	.504	91 (1)
HOPPER 1	(0, 0)-(0, 0)		.307	0.	0.	0.	0.	0.	.307	95 (1)
HOPPER 2	(0, 0)-(0, 0)	TU3	.255	.685E-01	.573E-01	0.	0.	0.	.331	99 (1)
HOPPER 2	(1, 1)-(3, 2)		.255	0.	0.	0.	0.	.100	.355	105 (1)

3 LEAST COST SYSTEMS

DREDGING EQUIPMENT	(TYPE,NO) TUG SCOW	TRAN UNIT	DREDGING	TRANSFER UNIT	TEMPORARY PIPELINE	FIXED PIPELINE	STATION TRANSFER	TUG/SCOW	TOTAL COST	SYSTEM NUMBER
HOPPER 1	(0, 0)-(0, 0)		.307	0.	0.	0.	0.	0.	.307	95 (1)
HOPPER 2	(1, 1)-(3, 2)		.255	0.	0.	0.	0.	.100	.355	105 (1)
HOPPER 2	(0, 0)-(0, 0)	TU3	.255	.685E-01	.573E-01	0.	0.	0.	.381	99 (1)

Table VII - 4

DREDGING AREAS	TENTATIVE SEDIMENT CLASSIFICATION (Applying Regional Water Quality Control Board Resolution 72-15)	DISPOSAL SITE
Suisun Bay Pt. Edith	Polluted with Organic Matter	Alcatraz
Mare Island Strait	Polluted with Heavy Metals	100 Fathom
Napa River	Polluted with Heavy Metals	100 Fathom
Petaluma River	Polluted with Organic Matter	Alcatraz
Pinole Shoal	Not Polluted	San Pablo
Richmond Long Wharf	Polluted with Heavy Metals	100 Fathom
San Rafael Creek	Polluted with Heavy Metals	100 Fathom
West Richmond Channel	Not Polluted	Alcatraz
Richmond Harbor & Pt. Molate	Polluted with Heavy Metals	100 Fathom
Oakland Inner and Outer Harbor and Alameda	Polluted with Heavy Metals	100 Fathom
San Francisco Harbor, Islais Cr., and Hunters Pt.	Polluted with Heavy Metals	100 Fathom
Redwood City Harbor	Polluted with Heavy Metals	100 Fathom

ALTERNATIVE DISPOSAL SCHEMES

Scheme I: Disposal Systems with Lowest Unit Cost to Aquatic Disposal Site at 100 Fathom Line

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	San Rafael Cr.	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site	100 Fathom Line											
System												
Hopper Dredge w/pumpout, scow, dump basin, fixed pipeline	(A) 0.74	(A) 0.66			(A) 0.62	(A) 0.76		(A) 0.65	(A) 0.80			
Hopper Dredge w/pumpout, bottom dump scow										(A) 0.86	(A) 0.80	(A) 0.91
Hopper Dredge (bottom dump)	(C) 2.47	(C) 2.33			(C) 1.93	(C) 1.95			(C) 2.01	(C) 2.15	(C) 1.98	(C) 2.46
18 cy Clam (mod), scow, S.P Terminus, fixed pipeline			(A) 1.17	(A) 1.28			(A) 1.05					
18 cy clam, scow	(B) 1.44 (D) 1.44	(B) 1.21 (D) 1.21		(B) 2.57 (D) 2.57	(B) 1.17 (D) 1.17	(B) 1.13 (D) 1.13	(B) 2.08 (D) 2.08	(B) 1.24 (D) 1.24	(B) 1.13 (D) 1.13	(B) 1.41 (D) 1.41	(B) 1.27 (D) 1.27	(B) 1.35 (D) 1.35
13 cy clam scow			(B) 2.00 (D) 2.00 (C) N/A	(C) N/A			(C) N/A					

Weighted Average Cost for System (A) = \$0.78/cu yd

Weighted Average Cost for System (B) = 1.36/cu yd

NOTES:

(1) Figure next to system description is cost \$ per cubic yard

(2) System Description

A. Least Cost System
B. Least Cost System using available equipment
C. Least Cost System using hopper dredge (available)
D. Least Cost System using clamshell dredge (available)

(3) Hopper dredge not applicable at Napa River, Petaluma River, and San Rafael Creek because of shallow water

(4) All cost are "bare" - do not include overhead, profit or supervision

ALTERNATIVE DISPOSAL SCHEMES

Scheme II: Disposal Systems with Lowest Unit Cost to Petaluma Land Disposal Site

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	San Rafael Creek	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site							Petaluma					
System												
Hopper dredge w/pumpout, scow, dump basin, fixed pipeline	(A) 0.78 (E) 0.78	(A) 0.70 (E) 0.70				(A) 0.80 (E) 0.80		(A) 0.69 (E) 0.69		(A) 0.97 (E) 0.97	(A) 0.91 (E) 0.91	(A) 1.05 (E) 1.05
Hopper dredge (bottom dump), dump basin, fixed pipeline					(A) 0.58 (E) 0.58				(A) 0.79 (E) 0.79			
18 cy clam (mod), scow S.Pablo Terminus, fixed pipeline			(A) 1.21 (E) 1.21	(E) 1.32			(A) 1.09 (E) 1.09					
18 cy clam, (mod) scow, fixed pipeline												
Hopper dredge w/pumpout, temporary pipeline	(F) 1.78	(F) 0.95			(F) 0.85	(F) 1.54		(F) 1.26		(F) 1.93		
18 cy clam (mod), temporary pipeline			(F) 2.26	(A) 1.22 (F) 1.22			(F) 3.22		(F) 1.54		(F) 2.96	(F) 3.24
Hopper dredge w/pumpout, scow, turning basin	(G) 0.86	(G) 0.78			(G) 0.73	(G) 0.90		(G) 0.83	(G) 0.91	(G) 1.05	(G) 0.99	(G) 1.12
18 cy clam (mod), scow turning basin			(G) 1.38	(G) 1.24			(G) 1.43					

Weighted Average Cost for System (A) = $0.81/cu yd ($0.62/cu yd for dredging and transport, $0.19/cu yd for site development and operation).

NOTES:

(1) Figure next to system description is cost $ per cubic yard (including $0.19/cu yd site development/operation)

(2) System Description

A. Least Cost System
E. Least Cost System using Fixed Pipeline
F. Least Cost System using Temporary Pipeline
G. Least Cost System using Turning Basin

(3) Hopper dredge not applicable at Napa River, Petaluma River and San Rafael Creek because of shallow water

(4) All costs are "bare"- do not include overhead, profit or supervision

ALTERNATIVE DISPOSAL SCHEMES

Scheme III: Disposal System with Lowest Unit Cost to Sherman Island Land Disposal

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	San Rafael Creek	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site	Sherman Island											
System												
Hopper dredge w/pumpout, scow, dump basin, fixed pipeline	(A) 0.91 (E) 0.91	(A) 0.83 (E) 0.83				(A) 0.92 (E) 0.92		(A) 0 82 (E) 0.82		(A) 1.09 (E) 1.09	(A) 1.03 (E) 1.03	(A) 1.18 (E) 1.18
Hopper dredge (bottom dump) dump basin, fixed pipeline					(A) 0.71 (E) 0.71				(A) 0.91 (E) 0.91			
18 cy clam, (mod), scow, fixed pipeline			(A) 1.34 (E) 1.34	(A) 1.45 (E) 1.45			(A) 1.21 (E) 1.21					
Hopper dredge w/pumpout, temporary pipeline	(F) 1.80	(F) 1.42			(F) 1.54					(F) 3.29		
18 cy clam (mod), temporary pipeline			(F) 3.25	(F) 5.03		(F) 3.05	(F) 8.53	(F) 3.82	(F) 3.37		(F) 5.14	(F) 4.86
Hopper dredge w/pumpout, scow, turning basin	(G) 0.95	(G) 1.01			(G) 1.04	(G) 1.28		(G) 1.19	(G) 1.32	(G) 1.44	(G) 1.37	(G) 1.56
18 cy clam (mod), scow, turning basin			(G) 1.71	(G) 2.60			(G) 2.32					
Hopper dredge, (bottom dump) scow turning basin												

Weighted Average Cost for System (A) = \$0.94/cu yd (\$0.77/cu yd for dredging and transport, \$0.17/cu yd for site development and operation)

NOTES:

(1) Figure next to system description is cost \$ per cubic yard (including \$0.17/cu yd for site development/operation)

(2) System Description

A. Least Cost System
E. Least Cost System using Fixed Pipeline
F. Least Cost System using Temporary Pipeline
G. Least Cost System using Turning Basin

(3) Hopper dredges not applicable at Napa River, Petaluma River, and San Rafael Creek because of shallow water

(4) All costs are "bare" - do not include overhead, profit or supervision

ALTERNATIVE DISPOSAL SCHEMES

Scheme IV: *Disposal System with Lowest Unit Cost (Closest Aquatic Disposal)*

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	S. Rafael Creek	W. Richmond Harbor	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal	Carquinez	Carquinez	Carquinez	San Pablo	Carquinez	San Pablo	San Pablo	San Pablo	San Pablo	Alcatraz	Hunter's Pt.	So. Bay
<u>Systems</u>												
Hopper dredge w/pumpout, bottom dump scow	(A) 0.40									(A) 0.54		
Hopper dredge (bottom dump)	(B) 0.45 (C) 0.45	(A) 0.31 (B) 0.31 (C) 0.31			(A) 0.25 (B) 0.25 (C) 0.25	(A) 0.45 (B) 0.45 (C) 0.45		(A) 0.37 (B) 0.37 (C) 0.37	(A) 0.52 (B) 0.52 (C) 0.52	(B) 0.70 (C) 0.70	(A) 0.27 (B) 0.27 (C) 0.27	(A) 0.31 (B) 0.31 (C) 0.31
18 cy clam (mod), bottom dump scow			(A) 0.76	(A) 1.09			(A) 0.66					
18 cy clam, bottom dump scow	(D) 1.18	(D) 0.90	(B) 1.19 (D) 1.19 (C) N/A	(B) 1.35 (D) 1.35 (C) N/A	(D) 0.88	(D) 1.00	(B) 0.92 (D) 0.92 (C) N/A	(D) 1.12	(D) 1.00	(D) 1.34	(D) 1.12	(D) 1.11

Weighted Average Cost for System (A) = $0.41/cu yd

Weighted Average Cost for System (B) = 0.47/cu yd

NOTES:

(1) Figure next to system description is $ per cubic yard

(2) System Description

A. Least Cost System
B. Least Cost System using available equipment
C. Least Cost System using hopper dredge (available)
D Least Cost System using clamshell dredge (available)

(3) Hopper dredge not applicable at Napa River, Petaluma River, and San Rafael Creek because of shallow water

(4) All costs are "bare" - do not include overhead, profit or supervision

ALTERNATIVE DISPOSAL SCHEMES

Scheme V: Disposal System with Lowest Unit Cost (Closest Seaward Aquatic Disposal Site)

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	S. Rafael Creek	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal	Carquinez	Carquinez	Carquinez	San Pablo	San Pablo	Alcatraz	Alcatraz	Alcatraz	Alcatraz	Alcatraz	Alcatraz	So. Bay
Systems												
Hopper dredge w/pumpout, bottom dump scow	(A) 0.40					(A) 0.50			(A) 0.55	(A) 0.54		
Hopper dredge (bottom dump)	(B) 0.45 (C) 0.45	(A) 0.31 (B) 0.31 (C) 0.31			(A) 0.29 (B) 0.29 (C) 0.29	(B) 0.63 (C) 0.63		(A) 0.37 (B) 0.37 (C) 0.37	(B) 0.57 (C) 0.57	(B) 0.70 (C) 0.70	(A) 0.46 (B) 0.46 (C) 0.46	(A) 0.31 (B) 0.31 (C) 0.31
18 cy clam (mod), bottom dump scow			(A) 0.76	(A) 1.09			(A) 0.86					
18 cy clam, bottom dump scow	(D) 1.18	(D) 0.90	(B) 1.19 (D) 1.19	(B) 1.35 (D) 1.35	(D) 0.88	(D) 1.00		(D) 1.12	(D) 1.00	(D) 1.34	(D) 1.12	(D) 1.11
13 cy clam, bottom dump scow							(B) 1.04 (D) 1.04					
			(C) N/A	(C) N/A								

Weighted Average Cost for System (A) = $0.44/cu yd

Weighted Average Cost for System (B) = 0.51/cu yd

NOTES:

(1) Figure next to system description is $ cost per cubic yard

(2) System Definitions

A. Least Cost System
B. Least Cost System using available equipment
C. Least Cost System using hopper dredge (available)
D. Least Cost System using clamshell dredge (available)

(3) Hopper dredges not applicable at Napa River, Petaluma River, and San Rafael Creek because shallow water

(4) *All costs are "bare" - do not include overhead, profit or supervision*

ALTERNATIVE DISPOSAL SCHEMES

Scheme VI: Disposal System with Lowest Unit Cost in Compliance with CRWQCB Criteria (Aquatic Disposal)

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	S. Rafael Creek	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal	Alcatraz	100 Fathom	100 Fathom	Alcatraz	San Pablo	100 Fathom	100 Fathom	Alcatraz	100 Fathom	100 Fathom	100 Fathom	100 Fathom
Systems												
Hopper dredge w/pumpout, bottom dump scow	(A) 0.64									(A) 0.86	(A) 0.80	(A) 0.91
Hopper dredge (bottom dump)	(C) 1.37	(C) 2.33			(A) 0.29 (B) 0.29 (C) 0.29	(C) 1.95		(A) 0.37 (B) 0.37 (C) 0.37	(C) 2.01	(C) 2.15	(C) 1.98	(C) 2.46
18 cy clam (mod), bottom dump scow				(A) 1.38								
18 cy clam, bottom dump scow	(B) 1.27 (D) 1.27	(B) 1.21 (D) 1.21		(B) 1.78 (D) 1.78	(D) 0.88	(B) 1.13 (D) 1.13	(B) 2.08 (D) 2.08	(D) 1.12	(B) 1.13 (D) 1.13	(B) 1.48 (D) 1.48	(B) 1.27 (D) 1.27	(B) 1.35 (D) 1.35
Hopper dredge w/pumpout, scow dump basin, fixed pipeline		(A) 0.68				(A) 0.77			(A) 0.82			
18 cy clam (mod) scow, S. Pablo terminus, fixed pipeline			(A) 1.19				(A) 1.06					
13 cy clam, scow			(B) 2.00 (D) 2.00									
			(C) N/A	(C) N/A			(C) N/A					

Weighted Average Cost for System (A) = $0.70 per cy

Weighted Average Cost for System (B) = 1.09 per cy

NOTES:

(1) Figure next to system description is $ cost per cubic yard

(2) System Definitions

A. Least Cost System
B. Least Cost System using available equipment
C. Least Cost System using hopper dredge (available)
D. Least Cost System using clamshell dredge (available)

(3) Hopper dredges not applicable at Napa River, Petaluma River, and San Rafael Creek because of shallow water

(4) All costs are "bare" - do not include overhead, profit or supervision

TABLE VII - 10

ALTERNATIVE DISPOSAL SCHEMES

Scheme VII: Disposal System with Lowest Cost in Compliance with CRWQCB Criteria (Aquatic Disposal Except Land Disposal in Place of 100 Fathom Line)

Dredge Site	Suisun Bay	Mare Island	Napa River	Petaluma River	Pinole Shoal	Richmond L.W.	S. Rafael Creek	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Disposal Site	Alcatraz	Petaluma	Petaluma	Alcatraz	San Pablo	Petaluma	Petaluma	Alcatraz	Petaluma	Petaluma	Petaluma	Petaluma
Systems												
Hopper dredge w/pumpout, scow, dump basin, fixed pipeline		(A) 0.71 (E) 0.71				(A) 0.80 (E) 0.80				(A) 0.97 (E) 0.97	(A) 0.91 (E) 0.91	(A) 1.06 (E) 1.06
Hopper dredge (bottom dump) dump basin, fixed pipeline									(A) 0.79 (E) 0.79			
18 cy clam (mod), scow, S. Pablo Terminus fixed pipeline			(A) 1.22 (E) 1.22				(A) 1.09 (E) 1.09					
Hopper Dredge w/pumpout, bottom dump scow	(A) 0.64											
18 cy clam (mod), bottom dump scow				(A) 1.35								
Hopper dredge w/pumpout, temporary pipeline		(F) 0.95				(F) 1.54				(F) 1.93		
18 cy clam (mod), temporary pipeline			(F) 2.26				(F) 3.22		(F) 1.54		(F) 2.96	(F) 3.2[illegible]
Hopper dredge (bottom dump),					(A) 0.29			(A) 0.37				
Hopper dredge w/pumpout, scow, turning basin		(G) 0.81				(G) 0.93			(G) 0.93	(G) 1.08	(G) 1.02	(G) 1.14
18 cy clam (mod), scow, turning basin			(G) 1.41				(G) 1.46					

Weighted Average Cost for System (A) = $0.73 per cy (includes $0.19 per cu. yd. site development and operation cost where disposal is at Petaluma site)

NOTES:

(1) Figure next to system description is cost $ per cubic yard (including $0.19/cu yd for site development/operation where applicable)

(2) System Description

A. Least Cost System
E. Least Cost System using Fixed Pipeline
F. Least Cost System using Temporary Pipeline
G. Least Cost System using Turning Basin

$\left.\begin{array}{l}\text{E.}\\\text{F.}\\\text{G.}\end{array}\right\}$ Land Disposal Site only

(3) Hopper dredges not applicable at Napa River, Petaluma River, and San Rafael Creek because of shallow water

(4) All costs are "bare" - do not include overhead, profit or supervision

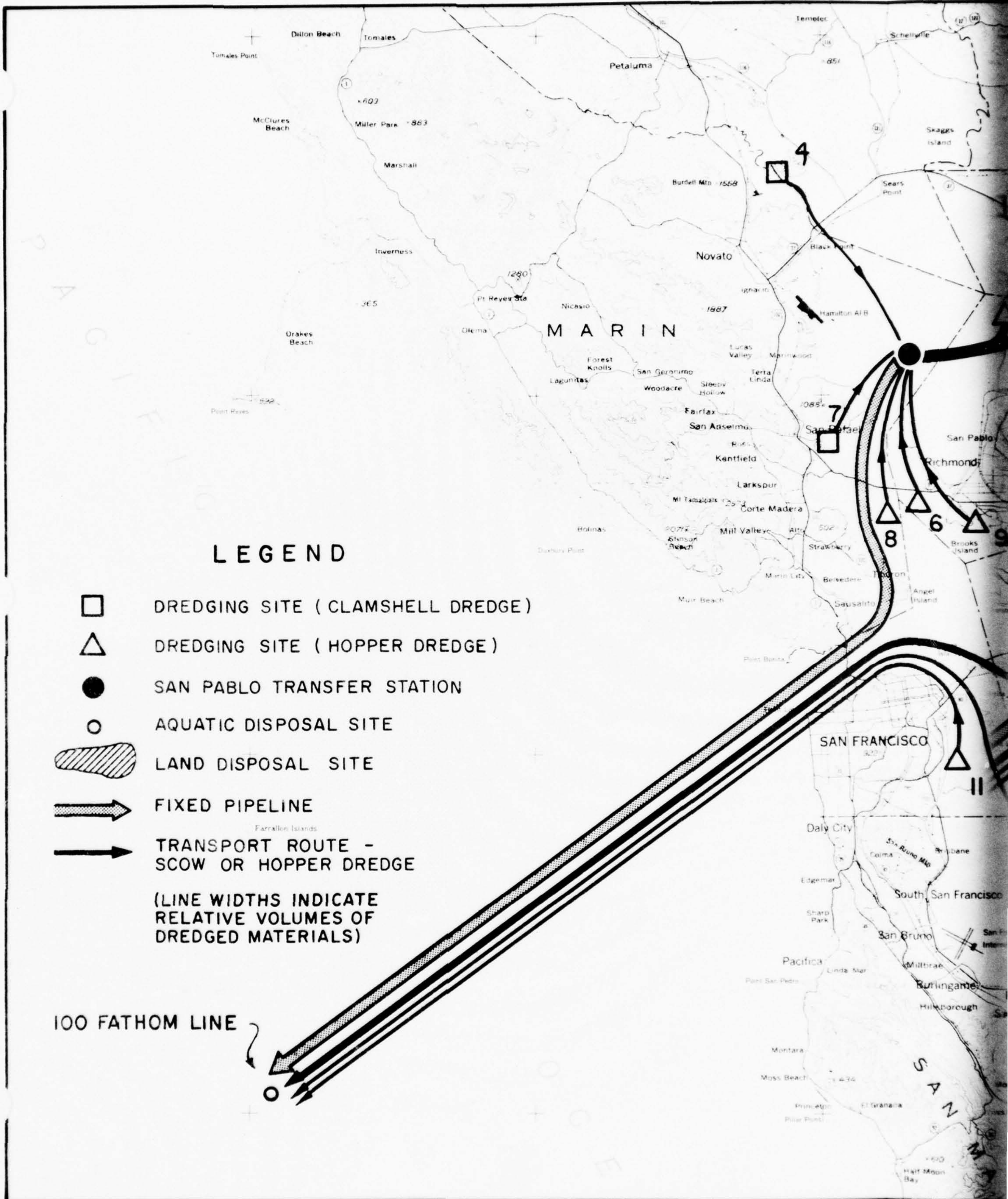
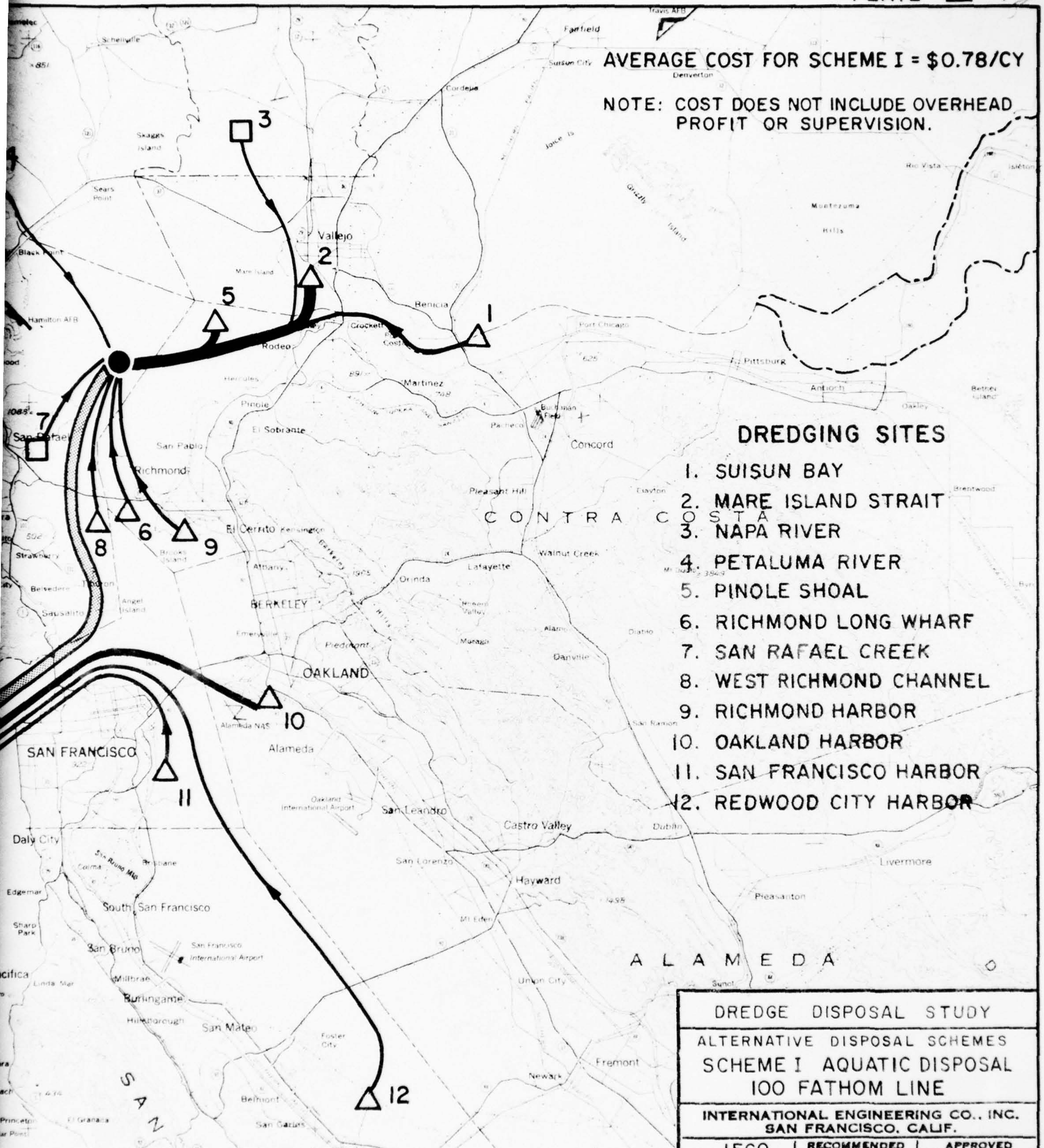
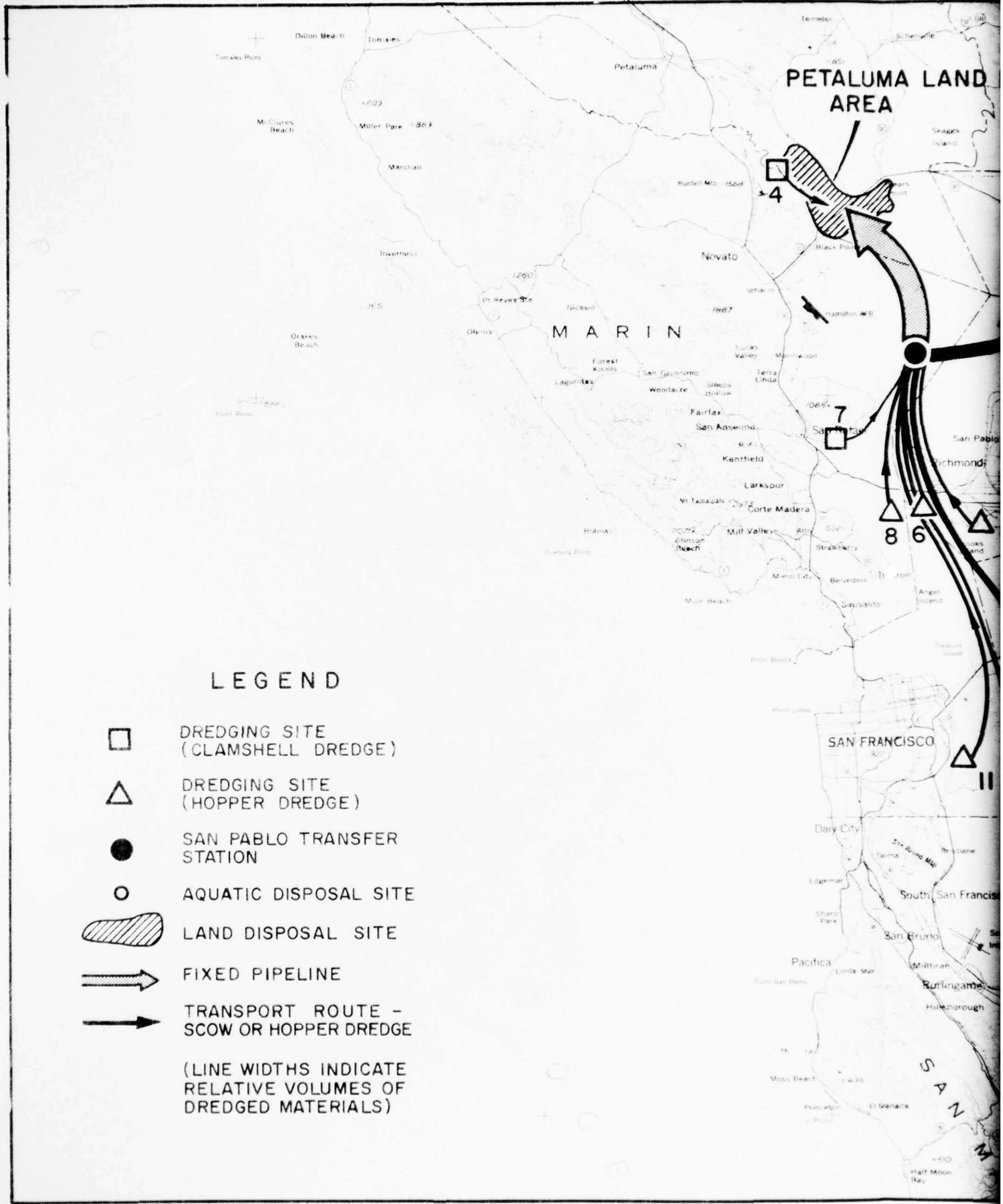
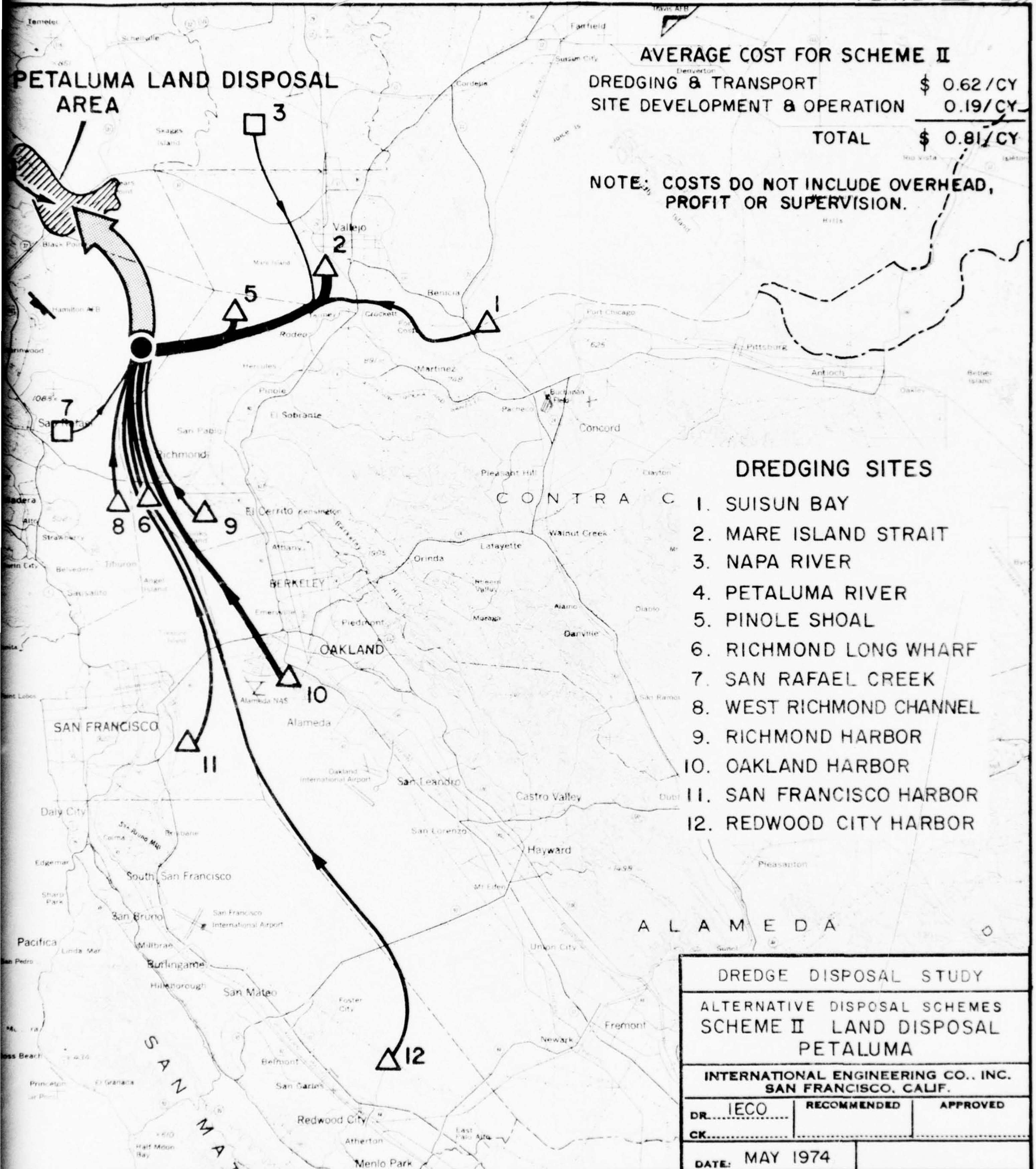
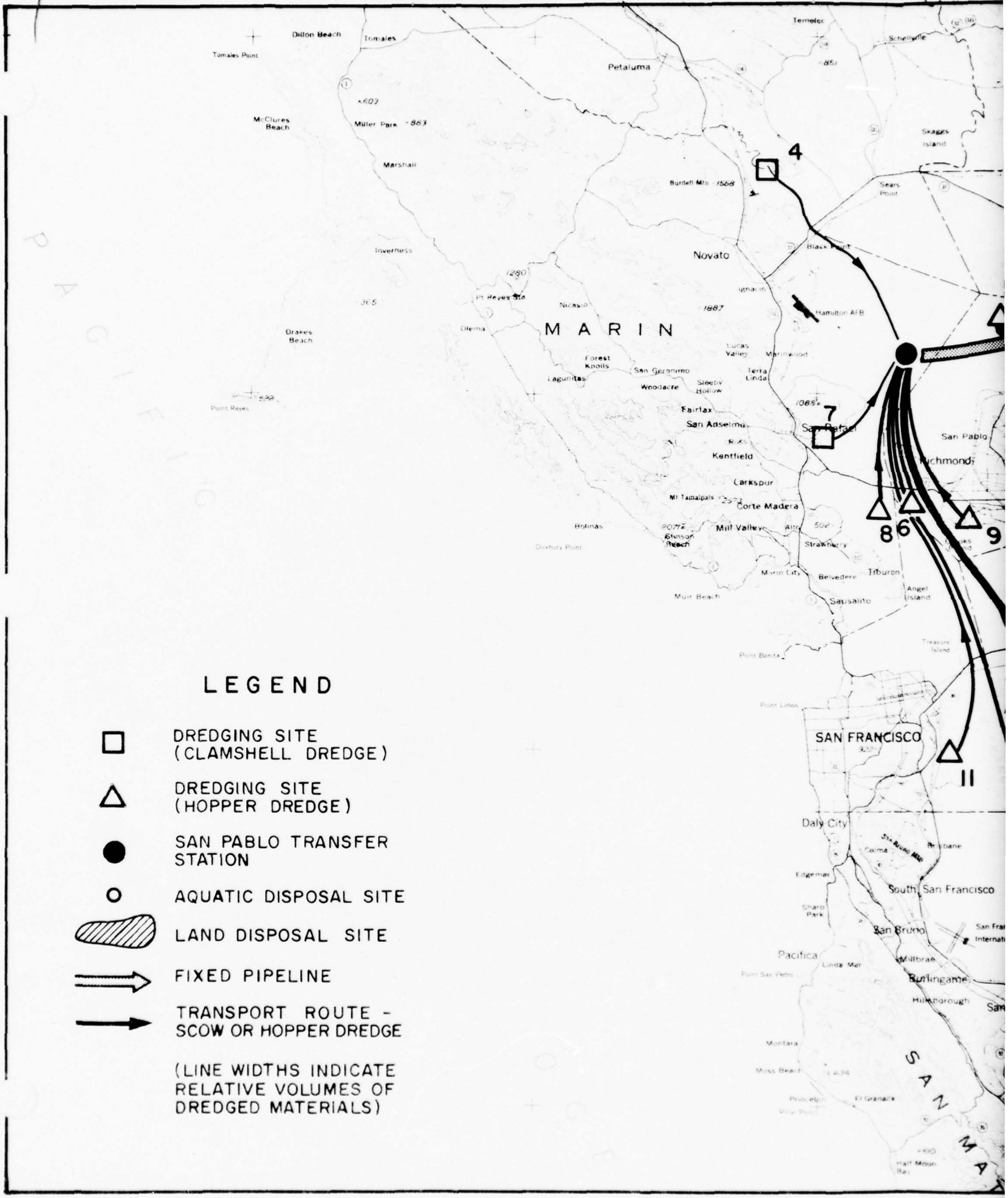

LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)
100 FATHOM LINE
MARIN
SAN FRANCISCO
Dillon Beach
Tomales
Tomales Point
Petaluma
McClures Beach
Miller Park
Marshall
Inverness
Pt Reyes Sta
Nicasio
Olema
Drakes Beach
Forest Knolls
Lagunitas
San Geronimo
Woodacre
Novato
Burdell Mtn
Black Point
Hamilton AFB
Lucas Valley
Terra Linda
Sleepy Hollow
Fairfax
San Anselmo
San Rafael
Kentfield
Larkspur
Corte Madera
Mill Valley
Bolinas
Stinson Beach
Strawberry
Belvedere
Tiburon
Sausalito
Muir Beach
Angel Island
Brooks Island
Richmond
San Pablo
Sears Point
Skaggs Island
Temelec
Schellville
Daly City
Brisbane
Colma
South San Francisco
Edgemar
Sharp Park
San Bruno
Pacifica
Linda Mar
Millbrae
Burlingame
Hillsborough
Montara
Moss Beach
Princeton
El Granada
Half Moon Bay
Farallon Islands
4
7
8
6
9
11

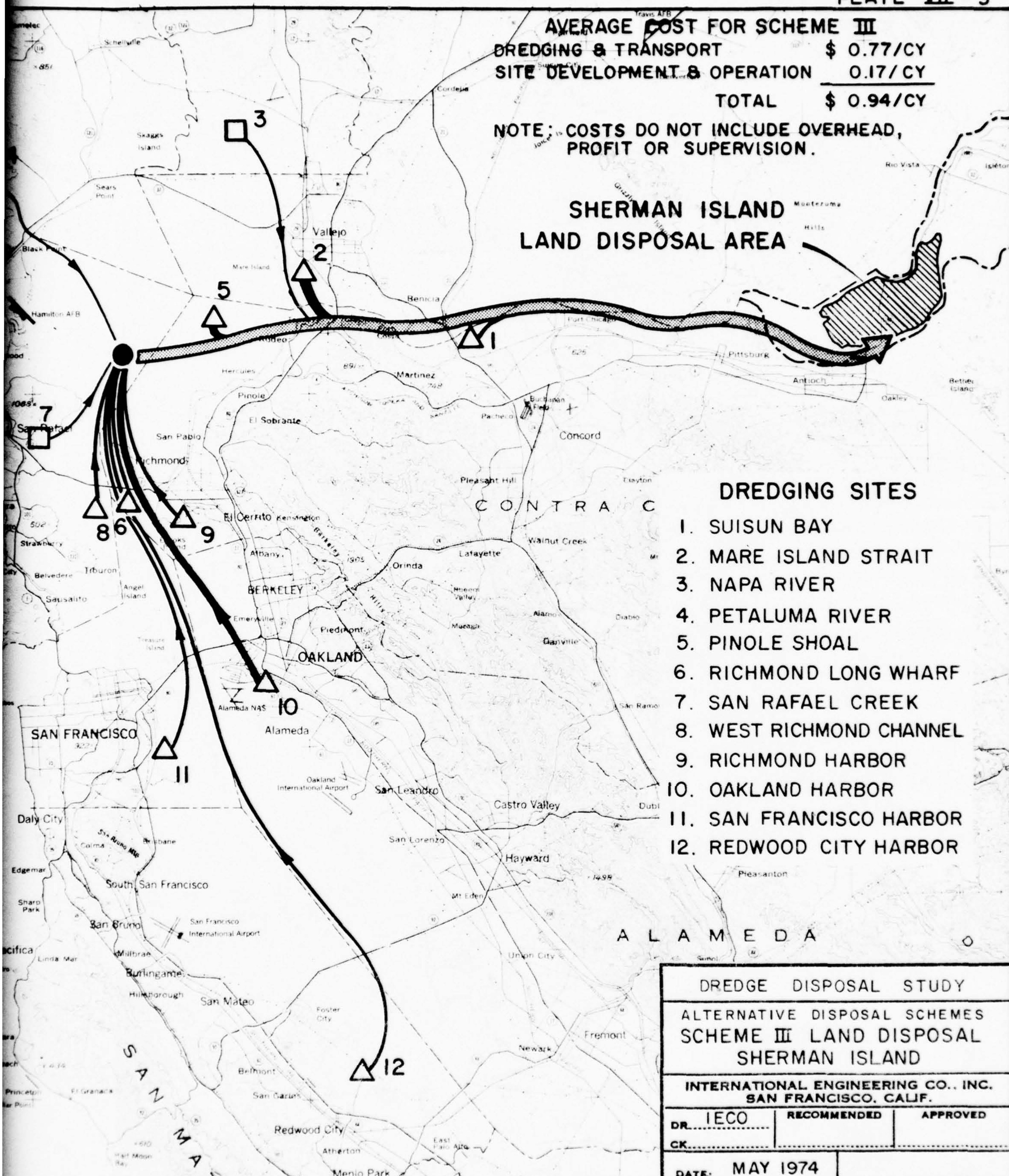
PLATE VII - I

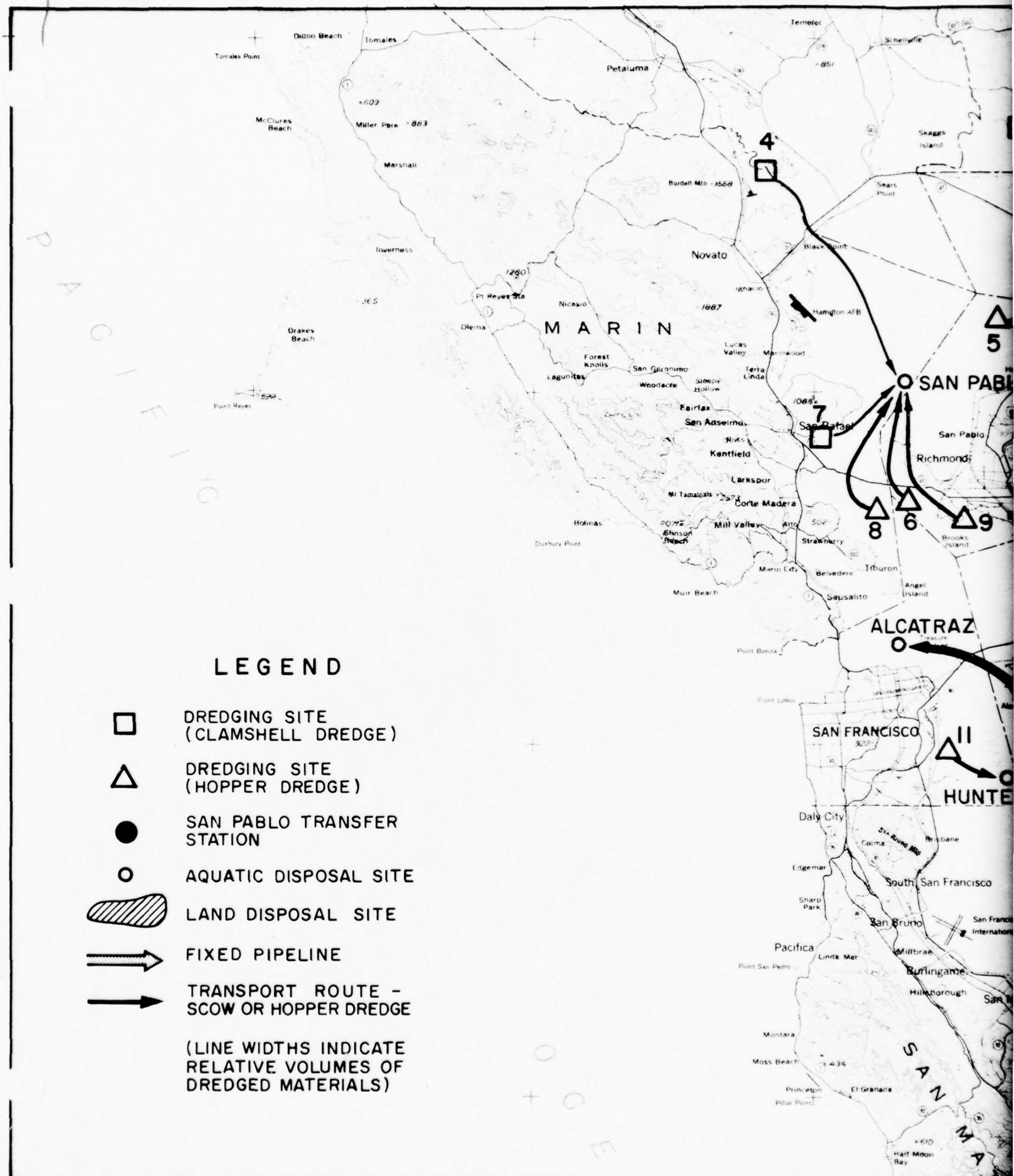

AVERAGE COST FOR SCHEME I = $0.78/CY
NOTE: COST DOES NOT INCLUDE OVERHEAD PROFIT OR SUPERVISION.
DREDGING SITES
1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR
CONTRA COSTA
ALAMEDA
SAN FRANCISCO
OAKLAND
BERKELEY
Vallejo
Richmond
Concord
Hayward
DREDGE DISPOSAL STUDY
ALTERNATIVE DISPOSAL SCHEMES
SCHEME I AQUATIC DISPOSAL
100 FATHOM LINE
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
CK.
RECOMMENDED
APPROVED
DATE: MAY 1974


PETALUMA LAND AREA
4
7
8
6
11
Petaluma
Novato
MARIN
San Rafael
Richmond
San Pablo
Kentfield
Larkspur
Corte Madera
Mill Valley
Sausalito
Belvedere
Tiburon
Angel Island
Fairfax
San Anselmo
SAN FRANCISCO
Daly City
South San Francisco
San Bruno
Pacifica
Millbrae
Burlingame
Hillsborough
Dillon Beach
Tomales
Marshall
Inverness
Drakes Beach
Olema
Bolinas
Stinson Beach
Muir Beach
Moss Beach
Half Moon Bay
LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)


AVERAGE COST FOR SCHEME II
DREDGING & TRANSPORT $ 0.62/CY
SITE DEVELOPMENT & OPERATION 0.19/CY
TOTAL $ 0.81/CY
NOTE: COSTS DO NOT INCLUDE OVERHEAD, PROFIT OR SUPERVISION.
PETALUMA LAND DISPOSAL AREA
DREDGING SITES
1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR
Vallejo
Benicia
Martinez
Concord
Richmond
El Cerrito
BERKELEY
OAKLAND
Alameda
SAN FRANCISCO
San Leandro
Castro Valley
Hayward
Daly City
South San Francisco
San Bruno
Pacifica
Burlingame
San Mateo
Fremont
Redwood City
Menlo Park
CONTRA C
ALAMEDA
SAN MA
DREDGE DISPOSAL STUDY
ALTERNATIVE DISPOSAL SCHEMES
SCHEME II LAND DISPOSAL
PETALUMA
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
CK.
RECOMMENDED
APPROVED
DATE: MAY 1974

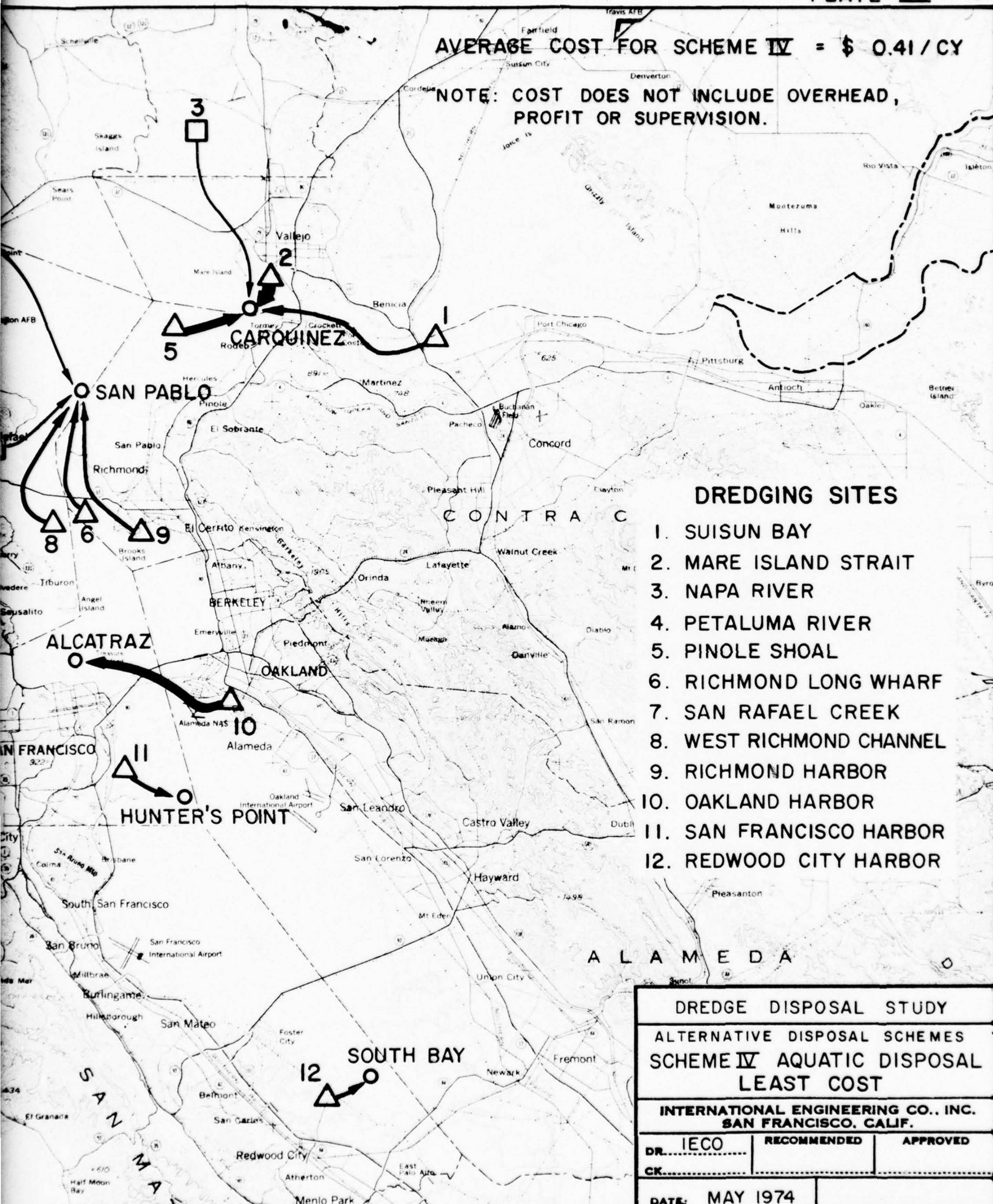

LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)
MARIN
SAN FRANCISCO
4
7
8
6
9
11
Dillon Beach
Tomales
Petaluma
Novato
Inverness
Olema
San Rafael
San Anselmo
Kentfield
Larkspur
Corte Madera
Mill Valley
Fairfax
Sausalito
Belvedere
Tiburon
Angel Island
Bolinas
Muir Beach
San Pablo
Richmond
Daly City
South San Francisco
San Bruno
Pacifica
Burlingame
Hillsborough
Brisbane
Montara
Moss Beach
Princeton
Half Moon Bay

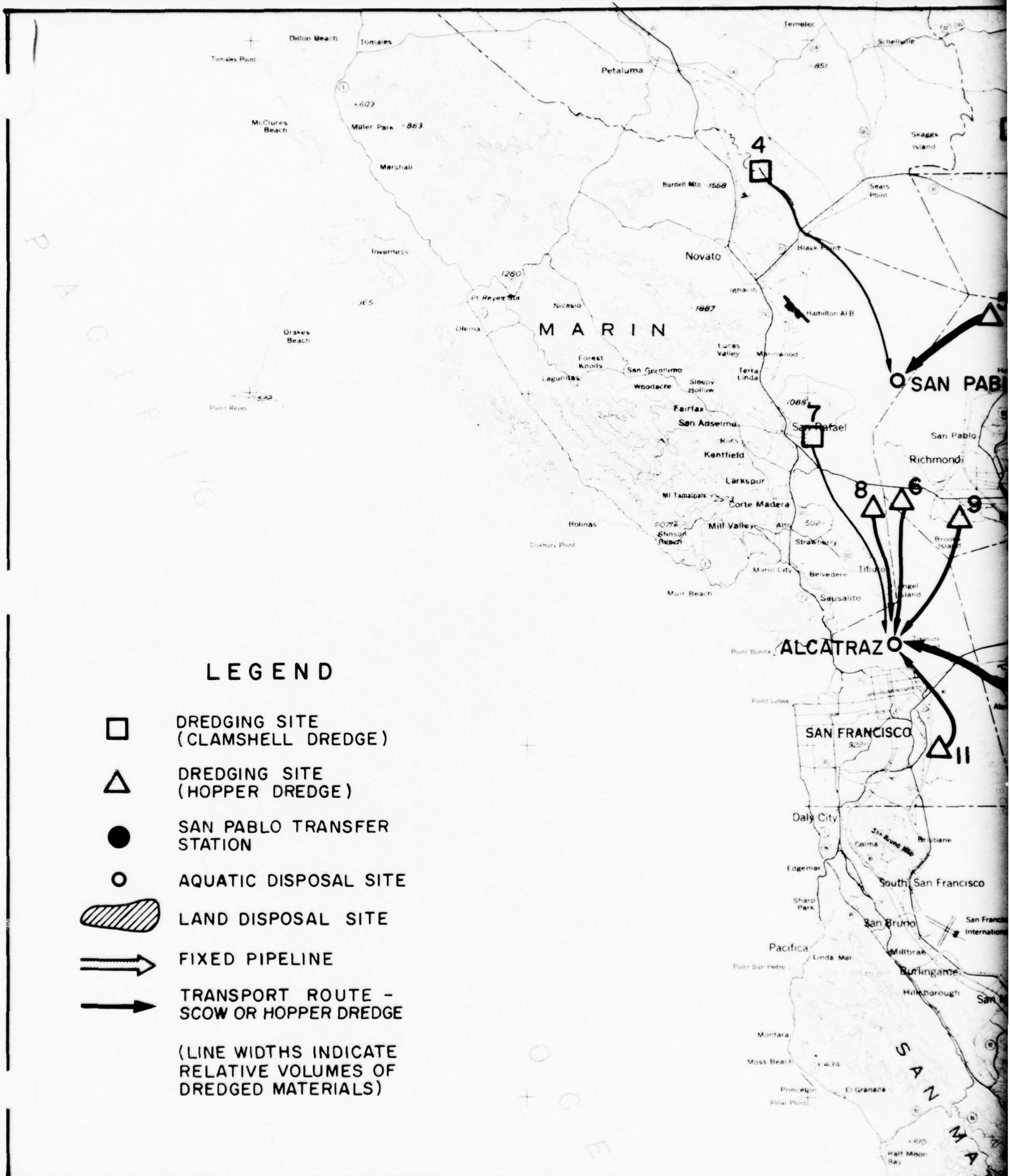

AVERAGE COST FOR SCHEME III
DREDGING & TRANSPORT $ 0.77/CY
SITE DEVELOPMENT & OPERATION 0.17/CY
TOTAL $ 0.94/CY
NOTE: COSTS DO NOT INCLUDE OVERHEAD, PROFIT OR SUPERVISION.
SHERMAN ISLAND LAND DISPOSAL AREA
DREDGING SITES
1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR
Vallejo
Benicia
Martinez
Pittsburg
Antioch
Concord
Richmond
BERKELEY
OAKLAND
Alameda
SAN FRANCISCO
Daly City
South San Francisco
San Mateo
Redwood City
Menlo Park
Hayward
San Leandro
Castro Valley
Fremont
CONTRA C
ALAMEDA
DREDGE DISPOSAL STUDY
ALTERNATIVE DISPOSAL SCHEMES
SCHEME III LAND DISPOSAL
SHERMAN ISLAND
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
CK.
RECOMMENDED
APPROVED
DATE: MAY 1974



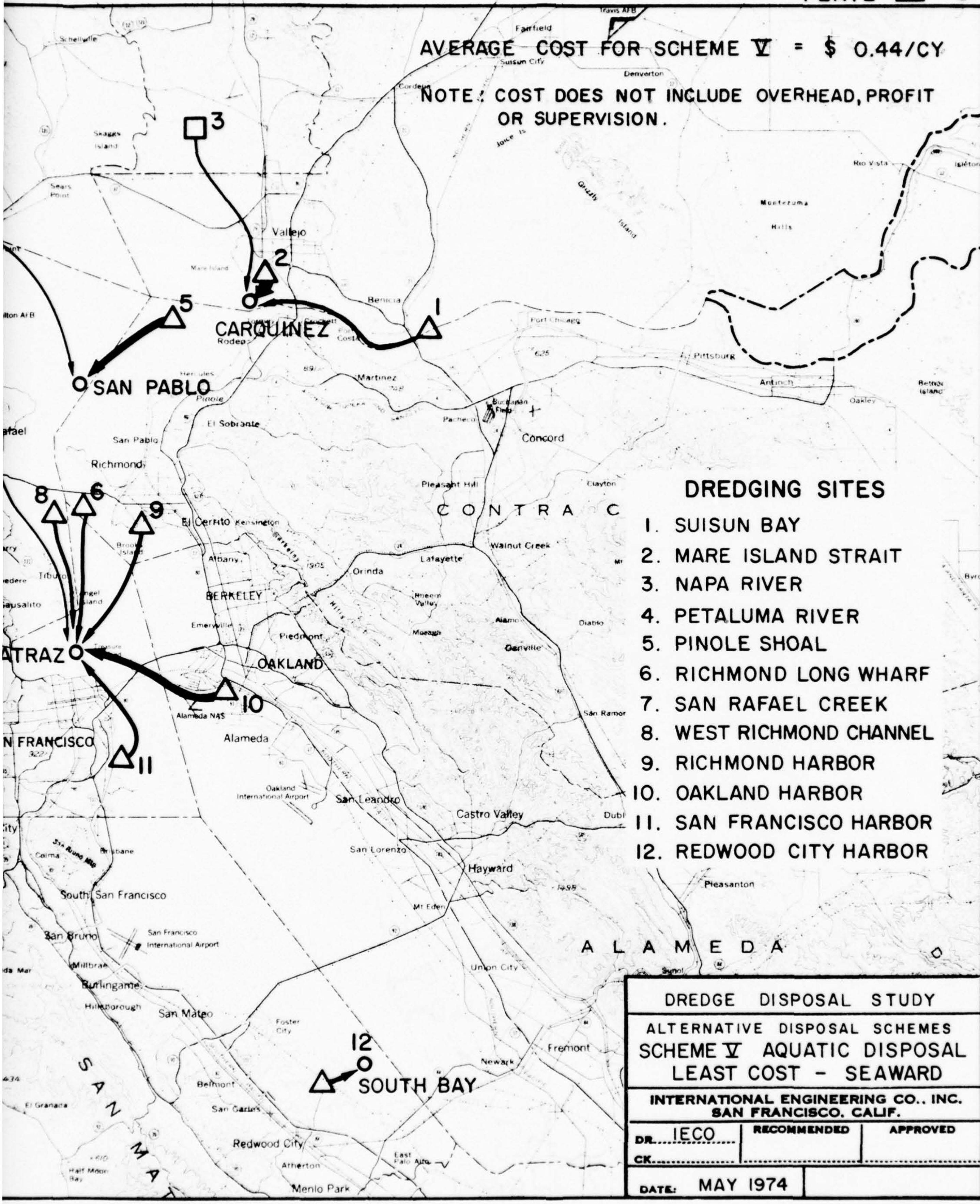
LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)
MARIN
SAN PABLO
ALCATRAZ
HUNTE
SAN FRANCISCO
4
5
6
7
8
9
11
Petaluma
Novato
San Rafael
Richmond
Sausalito
Tiburon
Mill Valley
Corte Madera
Larkspur
Kentfield
San Anselmo
Fairfax
Daly City
South San Francisco
Pacifica
San Bruno
Burlingame

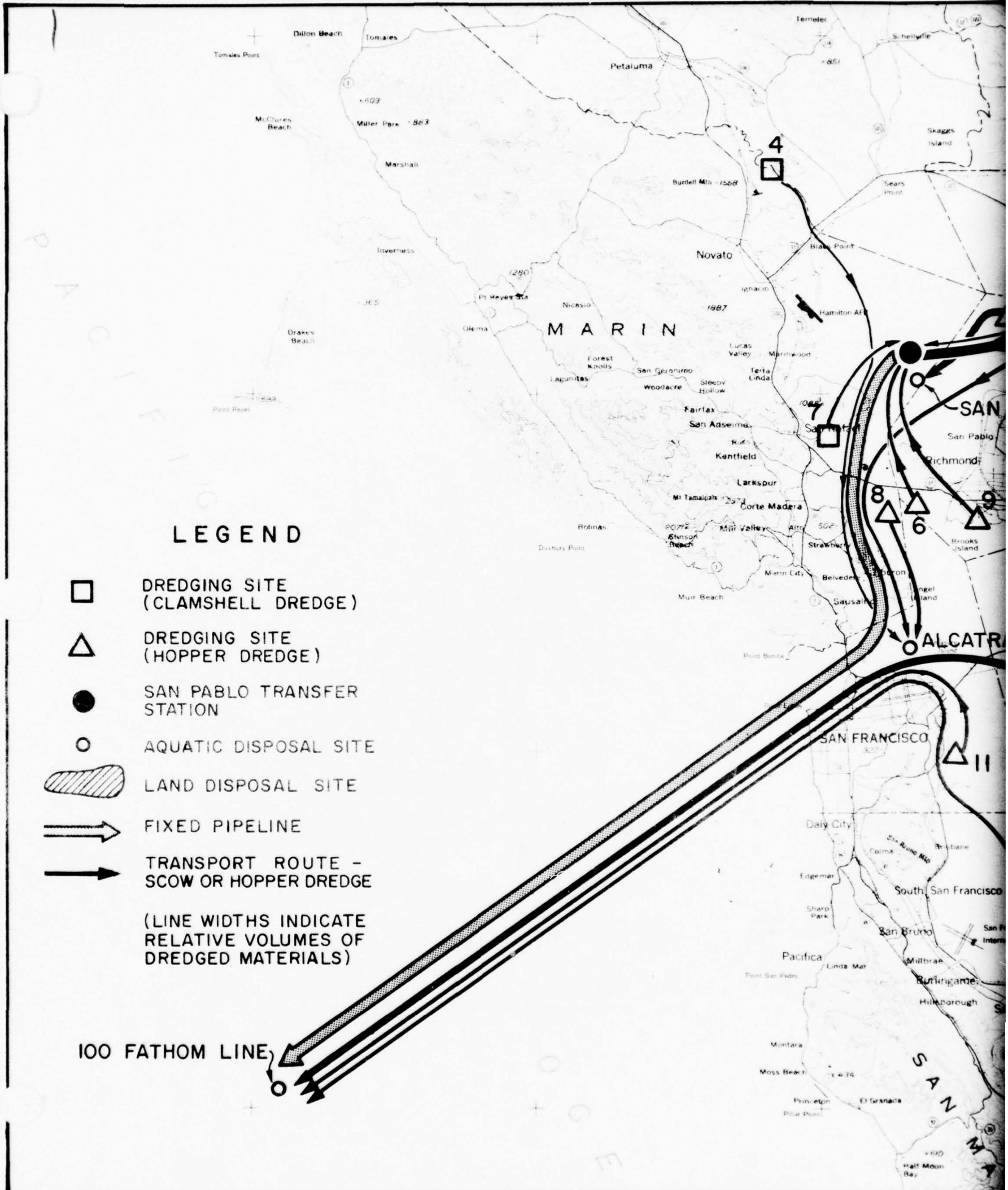
PLATE VII - 4


AVERAGE COST FOR SCHEME IV = $ 0.41 / CY
NOTE: COST DOES NOT INCLUDE OVERHEAD, PROFIT OR SUPERVISION.
DREDGING SITES
1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR
CARQUINEZ
SAN PABLO
ALCATRAZ
HUNTER'S POINT
SOUTH BAY
CONTRA C
ALAMEDA
Vallejo
Benicia
Martinez
Concord
Pittsburg
Antioch
Richmond
Berkeley
Oakland
Alameda
San Leandro
Hayward
Fremont
San Mateo
Redwood City
Menlo Park
DREDGE DISPOSAL STUDY
ALTERNATIVE DISPOSAL SCHEMES
SCHEME IV AQUATIC DISPOSAL
LEAST COST
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
CK.
RECOMMENDED
APPROVED
DATE: MAY 1974

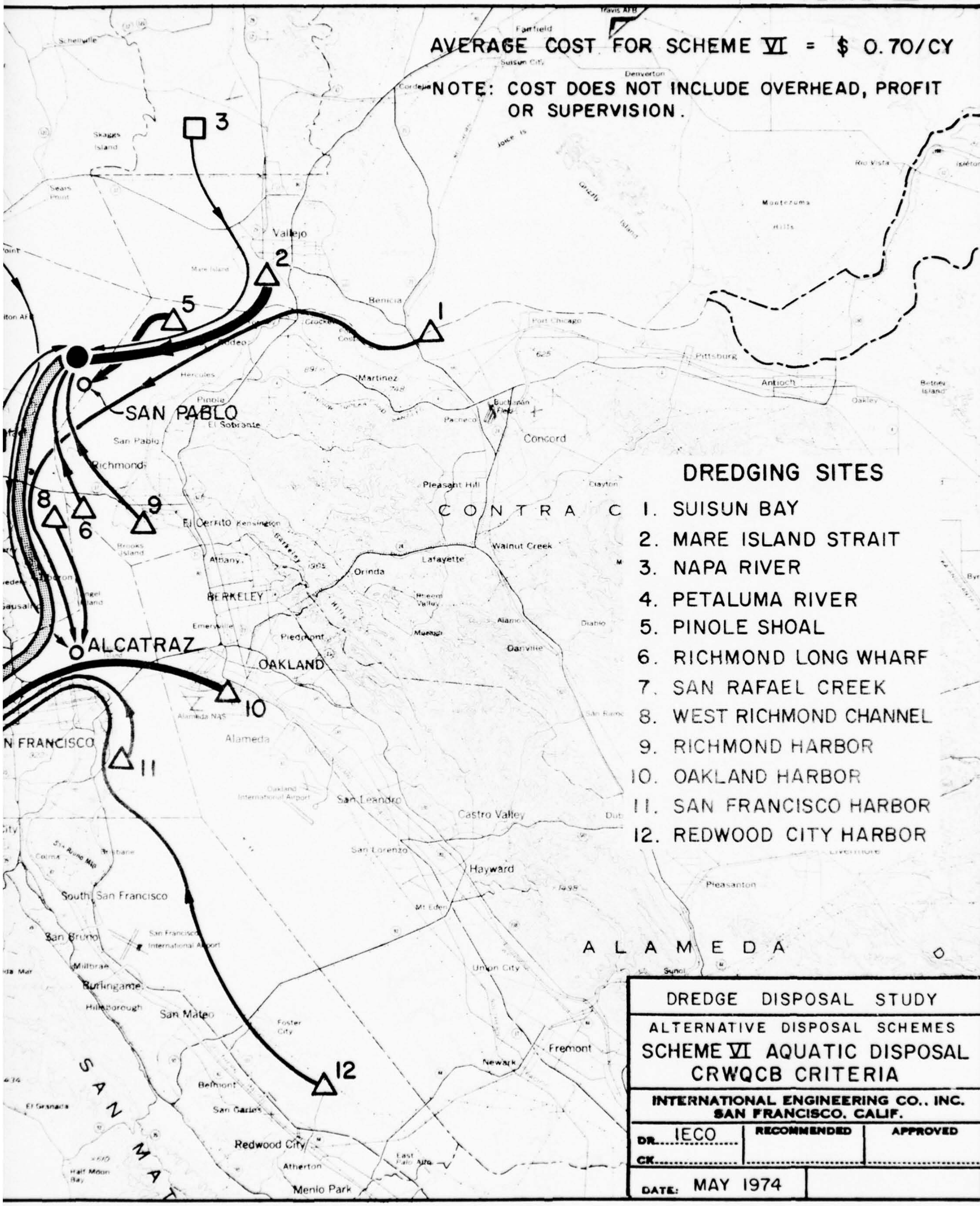


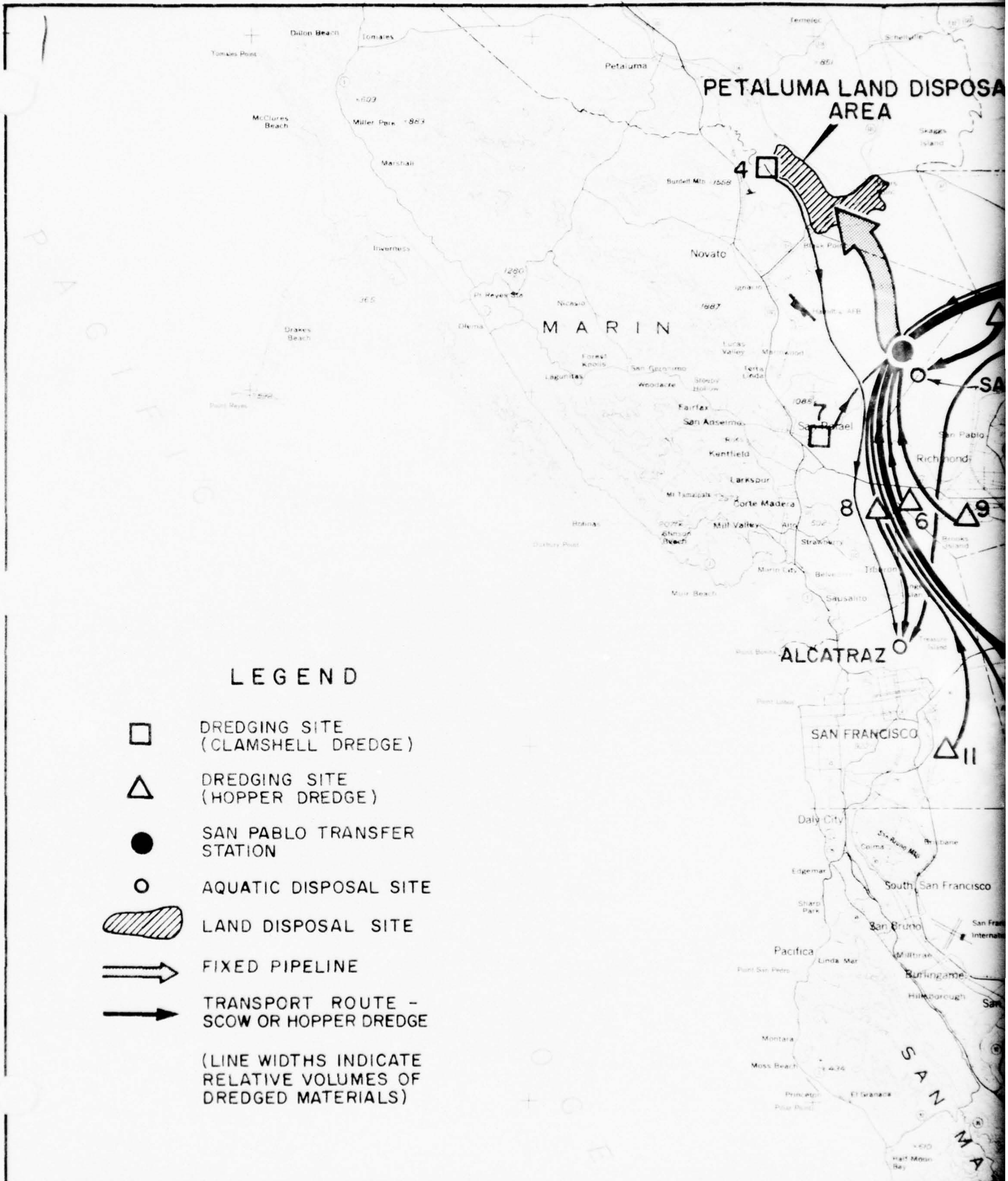
LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)
MARIN
SAN PAB
ALCATRAZ
SAN FRANCISCO
4
7
8
6
9
11
Dillon Beach
Tomales
Tomales Point
Petaluma
Temelec
Schellville
McClures Beach
Miller Park
Marshall
Skaggs Island
Sears Point
Burdell Mtn
Black Point
Novato
Inverness
Ignacio
Hamilton AFB
Pt Reyes Sta
Nicasio
Olema
Drakes Beach
Lucas Valley
Marinwood
Terra Linda
Forest Knolls
San Geronimo
Lagunitas
Woodacre
Sleepy Hollow
Fairfax
San Anselmo
San Rafael
San Pablo
Richmond
Kentfield
Larkspur
Corte Madera
Mill Valley
Bolinas
Stinson Beach
Strawberry
Belvedere
Tiburon
Sausalito
Muir Beach
Duxbury Point
Point Reyes
Point Bonita
Point Lobos
Daly City
Brisbane
Colma
Edgemar
South San Francisco
Sharp Park
San Bruno
Pacifica
Linda Mar
Millbrae
Burlingame
Hillsborough
Point San Pedro
Montara
Moss Beach
Princeton
El Granada
Pillar Point
Half Moon Bay


AVERAGE COST FOR SCHEME V = $ 0.44/CY
NOTE: COST DOES NOT INCLUDE OVERHEAD, PROFIT OR SUPERVISION.
DREDGING SITES
1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR
CARQUINEZ
SAN PABLO
ATRAZ
SOUTH BAY
CONTRA C
ALAMEDA
Vallejo
Benicia
Martinez
Concord
Richmond
El Cerrito
Albany
BERKELEY
OAKLAND
Alameda
San Leandro
Hayward
Castro Valley
Fremont
San Mateo
Burlingame
Redwood City
Menlo Park
South San Francisco
Pittsburg
Antioch
Rio Vista
Montezuma Hills
DREDGE DISPOSAL STUDY
ALTERNATIVE DISPOSAL SCHEMES
SCHEME V AQUATIC DISPOSAL
LEAST COST - SEAWARD
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
RECOMMENDED
APPROVED
CK.
DATE: MAY 1974



LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)
100 FATHOM LINE
MARIN
SAN FRANCISCO
ALCATRA
SAN
4
7
8
6
9
11
Petaluma
Novato
Tomales
Dillon Beach
Marshall
Inverness
Nicasio
Fairfax
San Anselmo
Kentfield
Larkspur
Corte Madera
Mill Valley
Sausalito
Belvedere
Daly City
South San Francisco
San Bruno
Pacifica
Millbrae
Burlingame
Hillsborough
Richmond
San Pablo


AVERAGE COST FOR SCHEME VI = $ 0.70/CY
NOTE: COST DOES NOT INCLUDE OVERHEAD, PROFIT OR SUPERVISION.
DREDGING SITES
1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR
SAN PABLO
ALCATRAZ
OAKLAND
Vallejo
Benicia
Martinez
Concord
Pittsburg
Antioch
Richmond
El Cerrito
Berkeley
Walnut Creek
Lafayette
Orinda
Alameda
San Leandro
Castro Valley
Hayward
South San Francisco
San Bruno
Burlingame
San Mateo
Redwood City
Menlo Park
Fremont
Newark
Pleasanton
CONTRA C
ALAMEDA
SAN MAT
DREDGE DISPOSAL STUDY
ALTERNATIVE DISPOSAL SCHEMES
SCHEME VI AQUATIC DISPOSAL
CRWQCB CRITERIA
INTERNATIONAL ENGINEERING CO., INC.
SAN FRANCISCO, CALIF.
DR. IECO
CK.
RECOMMENDED
APPROVED
DATE: MAY 1974

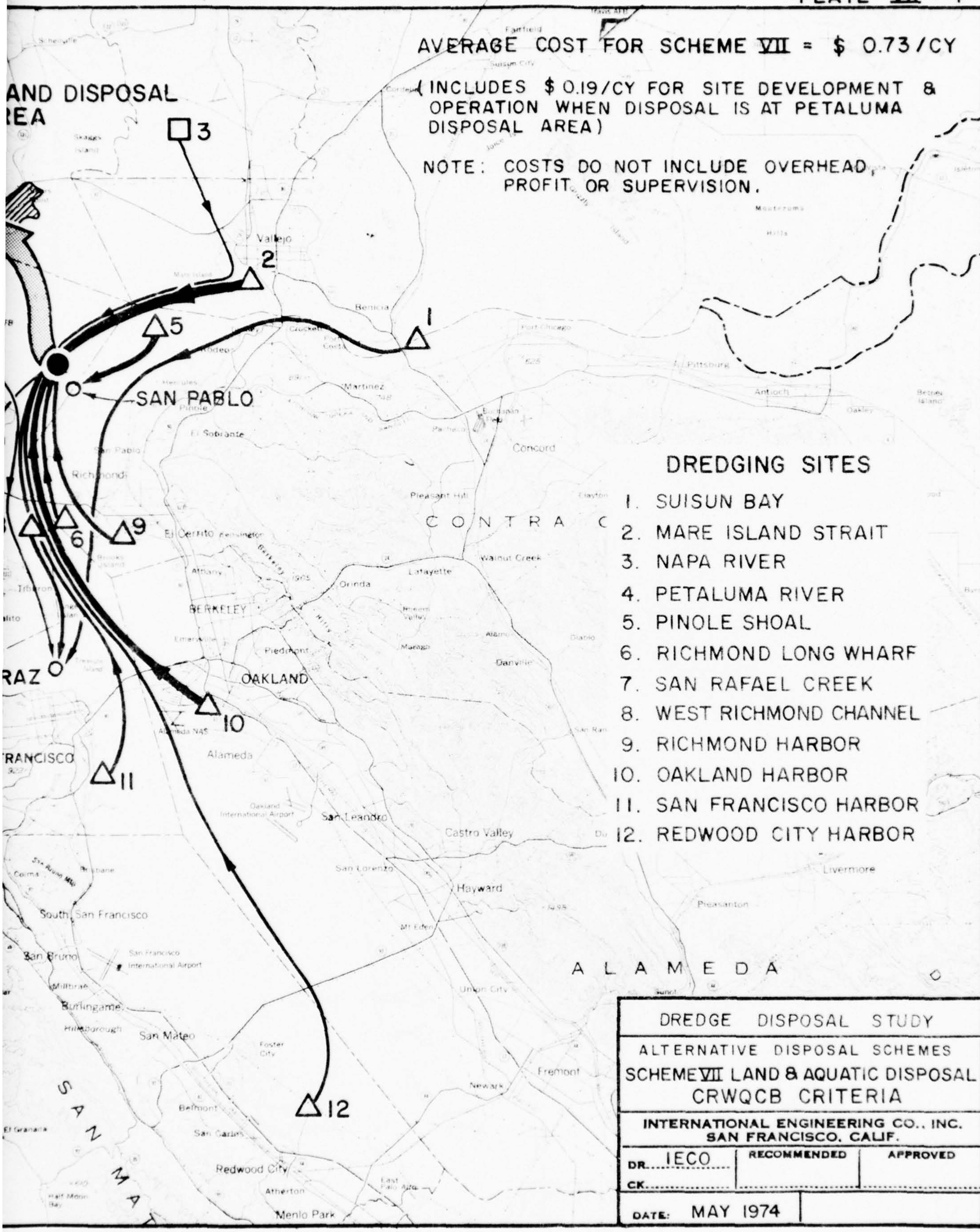


PETALUMA LAND DISPOSA
AREA
4
7
8
6
9
11
SA
ALCATRAZ
MARIN
Petaluma
Novato
Dillon Beach
Tomales
Tomales Point
McClures Beach
Miller Park
Marshall
Inverness
Drakes Beach
Point Reyes
Olema
Nicasio
Lagunitas
Woodacre
Fairfax
San Anselmo
Kentfield
Larkspur
Corte Madera
Mill Valley
Bolinas
Stinson Beach
Muir Beach
Sausalito
Tiburon
Belvedere
San Rafael
San Pablo
Richmond
SAN FRANCISCO
Daly City
Brisbane
Colma
South San Francisco
San Bruno
Millbrae
Burlingame
Hillsborough
Pacifica
Linda Mar
Edgemar
Sharp Park
Montara
Moss Beach
Princeton
El Granada
Half Moon Bay
SAN MA
LEGEND
DREDGING SITE (CLAMSHELL DREDGE)
DREDGING SITE (HOPPER DREDGE)
SAN PABLO TRANSFER STATION
AQUATIC DISPOSAL SITE
LAND DISPOSAL SITE
FIXED PIPELINE
TRANSPORT ROUTE - SCOW OR HOPPER DREDGE
(LINE WIDTHS INDICATE RELATIVE VOLUMES OF DREDGED MATERIALS)

AVERAGE COST FOR SCHEME VII = $ 0.73/CY

(INCLUDES $ 0.19/CY FOR SITE DEVELOPMENT & OPERATION WHEN DISPOSAL IS AT PETALUMA DISPOSAL AREA)

NOTE: COSTS DO NOT INCLUDE OVERHEAD, PROFIT OR SUPERVISION.



DREDGING SITES

1. SUISUN BAY
2. MARE ISLAND STRAIT
3. NAPA RIVER
4. PETALUMA RIVER
5. PINOLE SHOAL
6. RICHMOND LONG WHARF
7. SAN RAFAEL CREEK
8. WEST RICHMOND CHANNEL
9. RICHMOND HARBOR
10. OAKLAND HARBOR
11. SAN FRANCISCO HARBOR
12. REDWOOD CITY HARBOR

DREDGE DISPOSAL STUDY		
ALTERNATIVE DISPOSAL SCHEMES SCHEME VII LAND & AQUATIC DISPOSAL CRWQCB CRITERIA		
INTERNATIONAL ENGINEERING CO., INC. SAN FRANCISCO, CALIF.		
DR. IECO CK.	RECOMMENDED	APPROVED
DATE: MAY 1974		

APPENDIX A

CORE SAMPLING OF SEDIMENTS

Field Data

CORE SAMPLES OF SAN FRANCISCO BAY SEDIMENTS

Collected December 1973

For

INTERNATIONAL ENGINEERING COMPANY INC.

San Francisco, California

By

CSO LABORATORY

Concord, California

22 December 1973

22 December 1973

To: R. S. Samuelson/R. Krone
From: R. Carter
Re: Core Samples of San Francisco Bay Sediments

Ten general areas and twelve specific locations were sampled according to the schedule shown in Table I. The specific locations are shown on copies of the U. S. Corps of Engineers charts dated 30 June 1968. These charts are included with the field sheets of this report. The Suisun Bay chart was not available so an overlay of the Navagional Chart was prepared for the Station (No 10). The sample numbers are also given in Table I.

Table I

SAMPLING SCHEDULE

Station No.	Location	Date
1	San Francisco	6 Dec. '73
2 (1)	Redwood Creek	7
2 (2)	Redwood Creek	7
3	Oakland Outer Harbor	6
5	Richmond Harbor Entrance	10
7	San Rafael Creek	10
8 (1)	Pinole Shoal	11
8 (2)	Pinole Shoal	11
9	Mare Island	12
10	Suisun Bay	12
11	Napa River	17
12	Petaluma River	17

The samples were collected by means of a 3-inch diameter corer. Three-one-gallon samples were composited from 6 to 12 cores. A 25 lb sample of core material was collected from both Redwood Creek (Sta 2-1) and Pinole Shoal (Sta 8-1). A sealed undisturbed core was collected from each station (except 2-2). A pt representative sample (2 pints or 1 qt) was collected from each station, and a qt center section of core was taken and sealed for moisture determination from each station.

Fathometer charts of the bottom profile were made as indicated on the field data records. The individual transects were labled a, b, c, etc., and a non-scale sketch showing orentation of the transects is shown on the redraft of the field sheets. The actual or observed depth of water during sampling is reported on the field records. The calculated depth at MLLW is also given.

The Physical data is reported in Table II below. A copy of the chemical analysis from the melt from which the core tool was constructed is attached.

Table II

PHYSICAL DATA

Station No.	Location	Apparent Density, gm/cc	Force* to Penetrate, lbs	Percent Water PW	PWW
1	San Francisco	1.48	85	74.5	42.7
2 (1)	Redwood Creek	1.33	100	172.0	63.3
2 (2)	Redwood Creek	1.38	90	140.5	58.5
3	Oakland Outer Harbor	1.43	115	123.5	55.3
5	Richmond Harbor Entrance	1.52	185	75.9	43.2
7	San Rafael Creek	1.39	185	113.0	53.0
8 (1)	Pinole Shoal	1.64	300**	72.3	42.0
8 (2)	Pinole Shoal	1.64	300**	41.3	29.2
9	Mare Island Strait	1.30	136	102.0	50.5
10	Suisun Bay	1.64	285	49.3	33.0
11	Napa River	1.61	100	82.0	45.1
12	Petaluma River	1.39	60	111.8	52.8

* Loading on 3" core penetrating 2 ft of sediment.

** Estimated from free fall of 145 lb core device through water column.

$$PWW = \frac{PW}{PW + 100}$$

SAMPLING DATA

Sample No 1
Date 6 December 1973
Time 0908 - 1120

Location: San Francisco
Depth: 42 1/2 Ft, 36 ft (MLLW)
Tidal Condition 6 1/2 ft, start of Ebb
Currents North Set, 3/4 k → 2 k +
General Appearance Gray black to brown silty clay
Odor normal marine sediment Penetration 85 lbs for 2 ft core

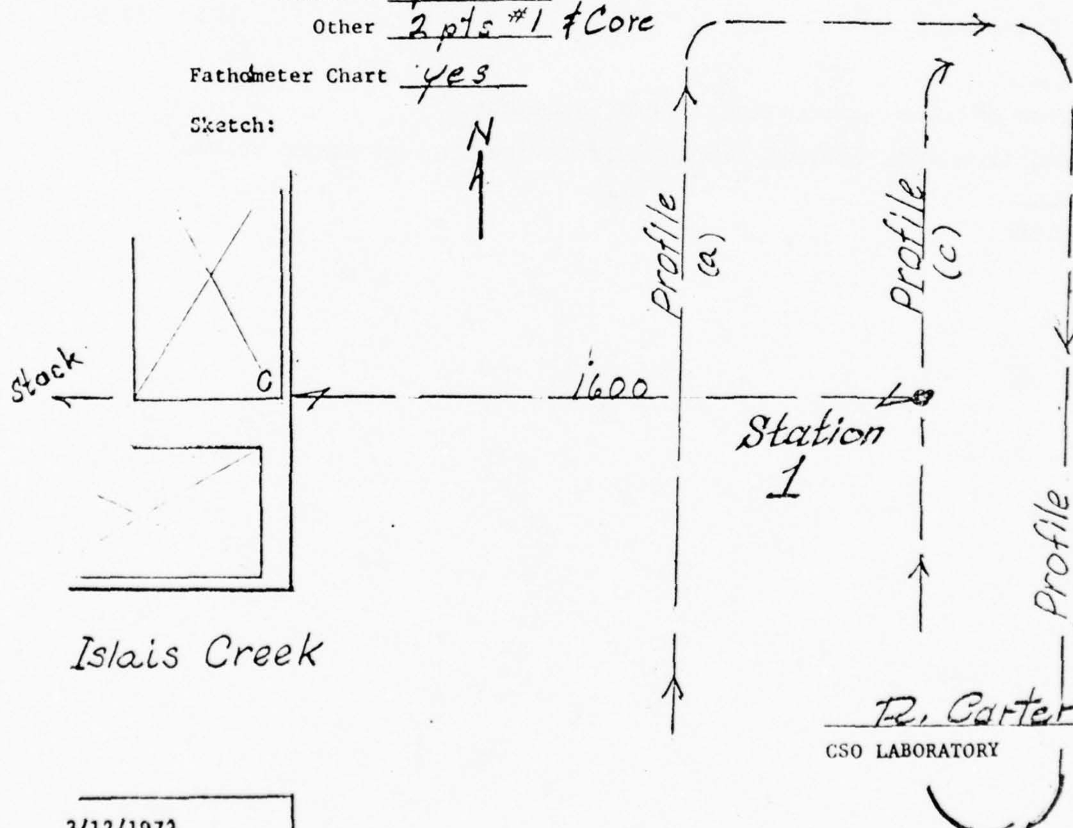
Bulk Density: Gross Weight 3,290 gm
Tare 697
Net 2,593
Density 1.48

Volume:
Length 46 cm
Area 38
Volume 1,750

Samples: Bulk 1a, b & c
Moisture 1
Other 2 pts #1 & Core

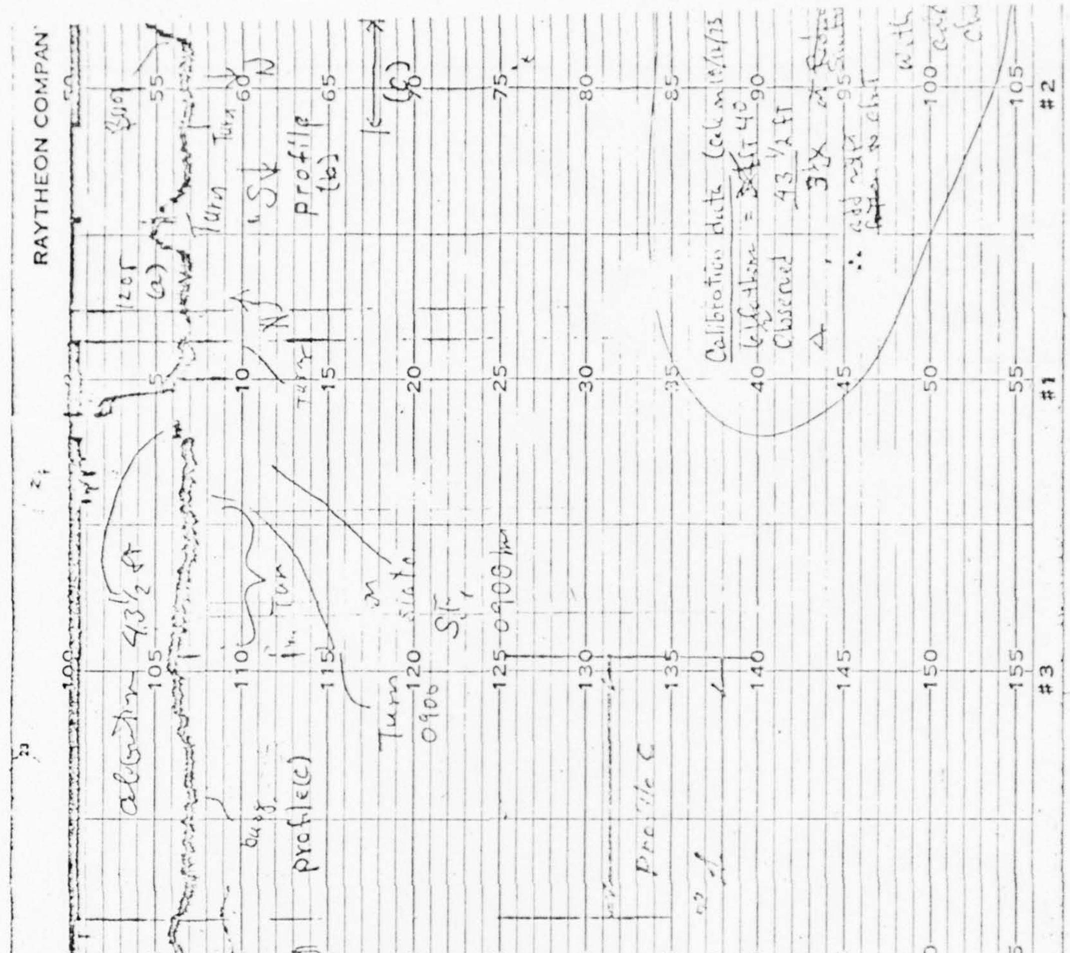
Fathometer Chart yes

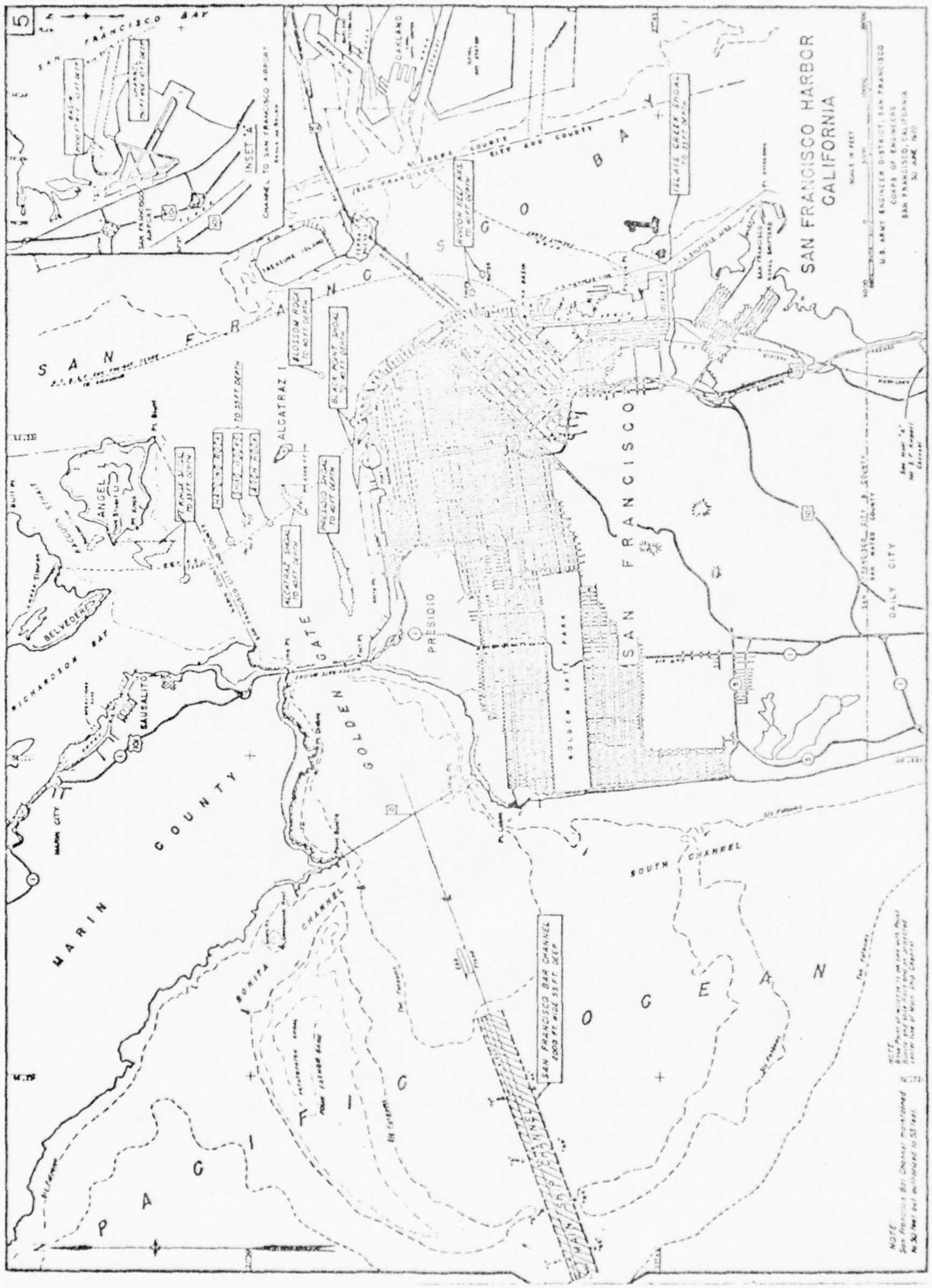
Sketch:



R. Carter
CSO LABORATORY

3/12/1973


DEPTH IN FATHOMS
RAYTHEON COMPANY
155-1002-G1
Profile (a)
Profile (b)
Profile (c)
Profile B
Profile C
Turn


SAN FRANCISCO HARBOR
CALIFORNIA
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
SAN FRANCISCO BAY
INSET 'A'
OAKLAND
TREASURE ISLAND
ALCATRAZ
ANGEL I.
BELVEDERE
RICHARDSON BAY
SAUSALITO
MARIN COUNTY
GOLDEN GATE
PRESIDIO
SAN FRANCISCO
DALY CITY
SOUTH CHANNEL
BONITA CHANNEL
PACIFIC OCEAN
SAN FRANCISCO BAR CHANNEL
BLOSSOM ROCK
ISLAIS CREEK SHOAL
RINCON REEF AREA
ALCATRAZ SHOAL
PRESIDIO SHOAL
BLACK POINT SHOAL
GOLDEN GATE PARK

SAMPLING DATA

Sample No 2(1)
Date 7 Dec 1973
Time 1006-1210

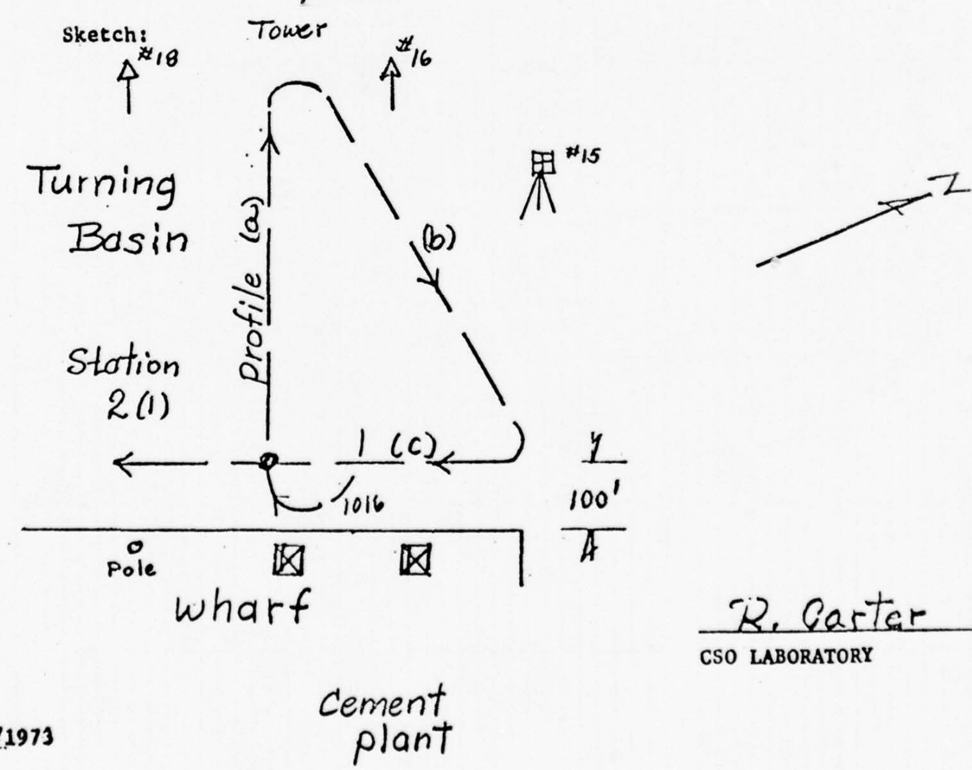
Location: Redwood City Turning Basin
Depth: 34 Ft, 26 ft MLLW
Tidal Condition 8 ft tide on Ebb
Currents Slack to 1/2 k
General Appearance black to brown fine sandy silt
Odor Bay Mud, Penetration 100 lbs for 2 ft core

Bulk Density:			Volume:	
	Gross Weight	3,970 gm		
	Tare	704	Length	64.5 cm
	Net	3,266	Area	38
	Density	1.33	Volume	2,460

Samples: Bulk 2(1) a, b, & c.
Moisture 2(1)
Other 2-2(1) pts. core # 25 lb bulk

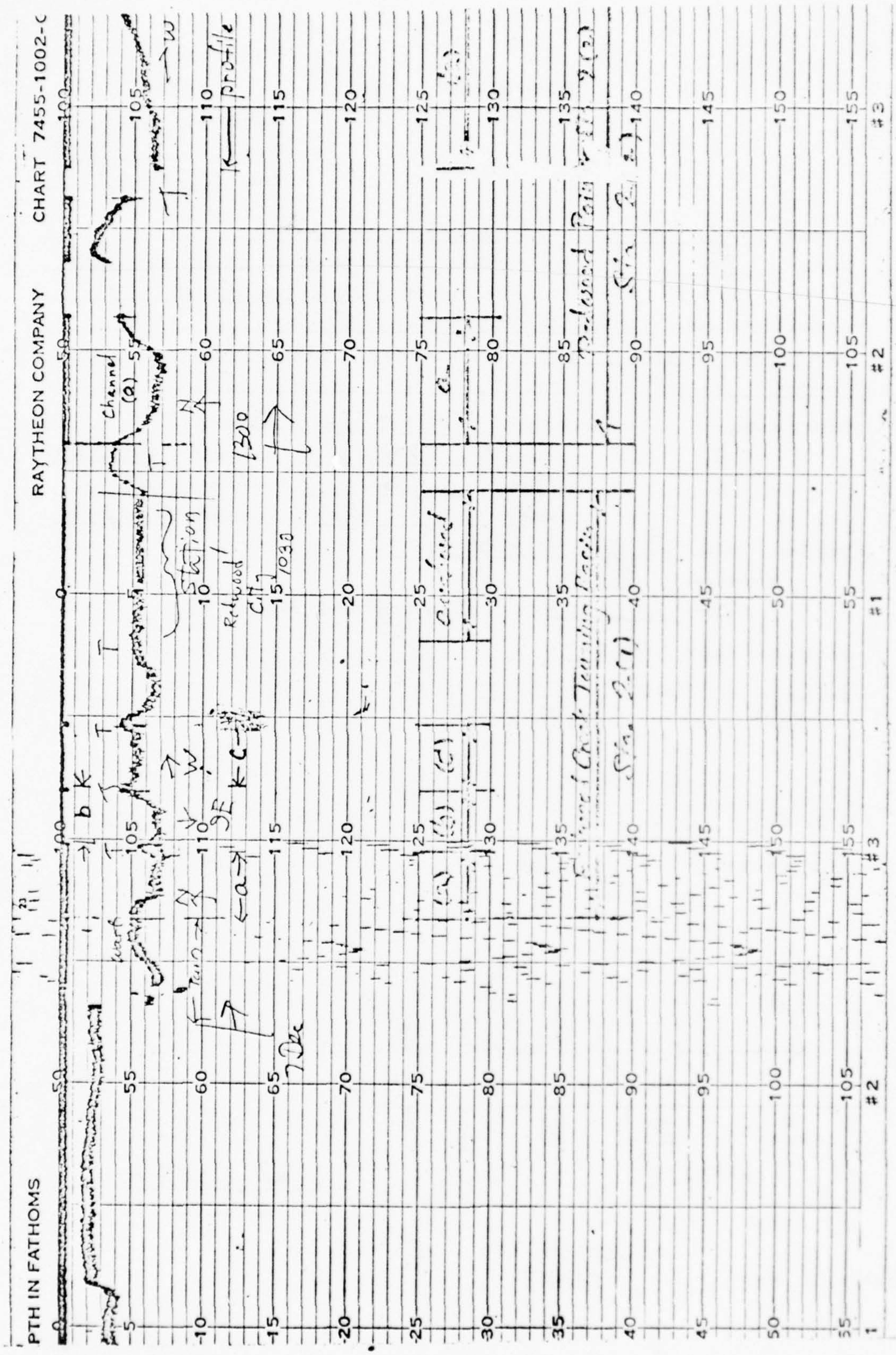
Fathometer Chart yes

Sketch:



R. Carter
CSO LABORATORY

3/12/1973


PTH IN FATHOMS
RAYTHEON COMPANY
CHART 7455-1002-C
Channel (2)
Station
Redwood City
1030
1300
profile
7 Dec

SAMPLING DATA

Sample No 2(2)
Date 7 Dec 1973
Time 1300-1415

Location: Redwood Point

Depth: 24-25 Ft, 23 @ MLLW

Tidal Condition 3-4 ft tide on Ebb

Currents 3/4 to 1 K set Northeast

General Appearance black to brown silty clay

Odor trace H_2S, Penetration 90 lbs force for a 2 ft core.

Bulk Density:

Gross Weight 4,370*
Tare 1,725*
Net 2,645
Density 1.38

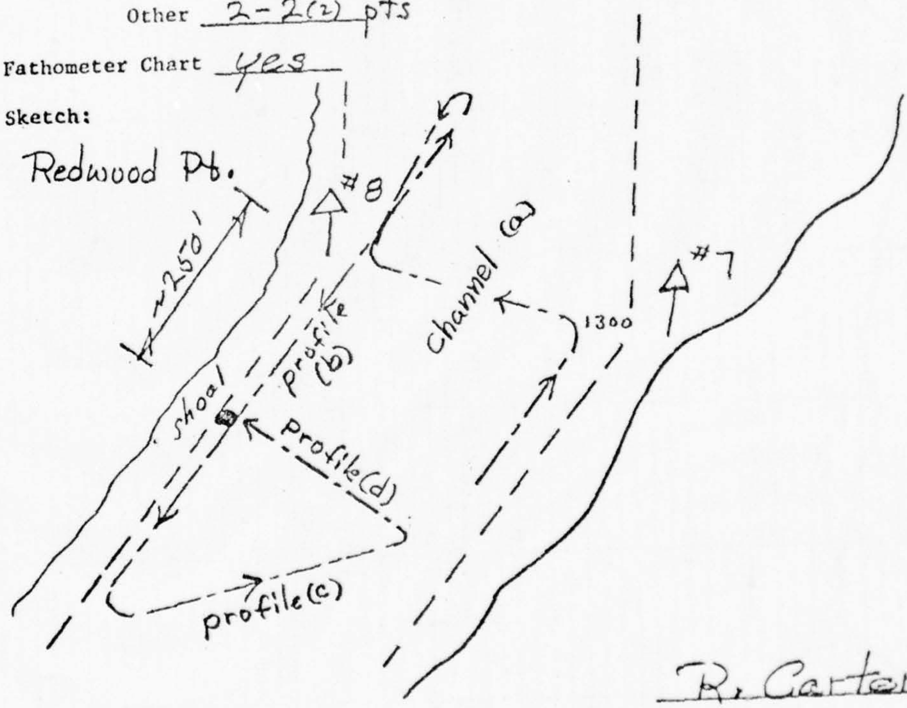
Volume:

Length 75.5cm
Area 25.5*
Volume 1,925

Samples: Bulk 2(2) a, b, & c.
Moisture 2(2)
Other 2-2(2) pts

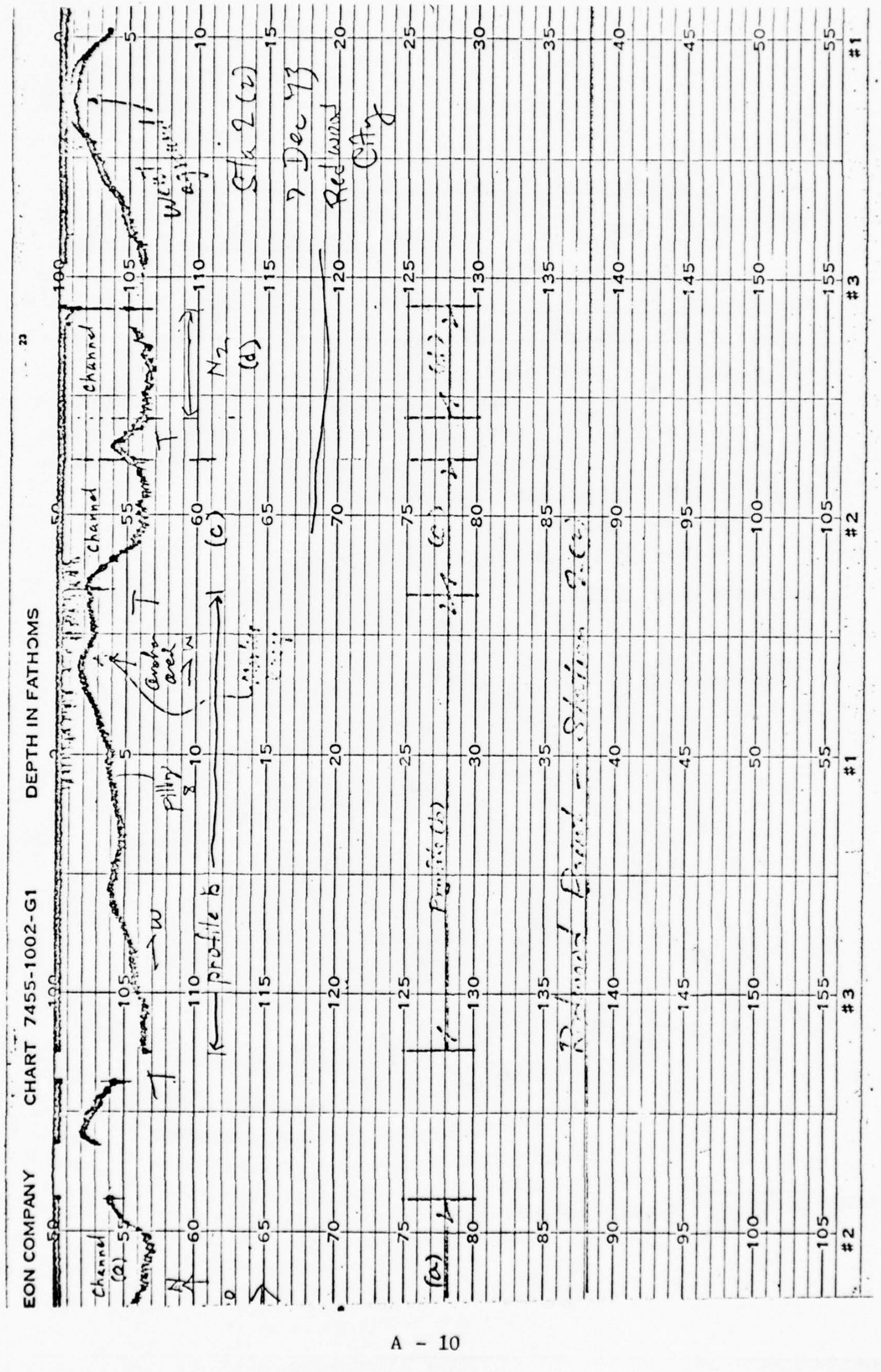
Fathometer Chart yes

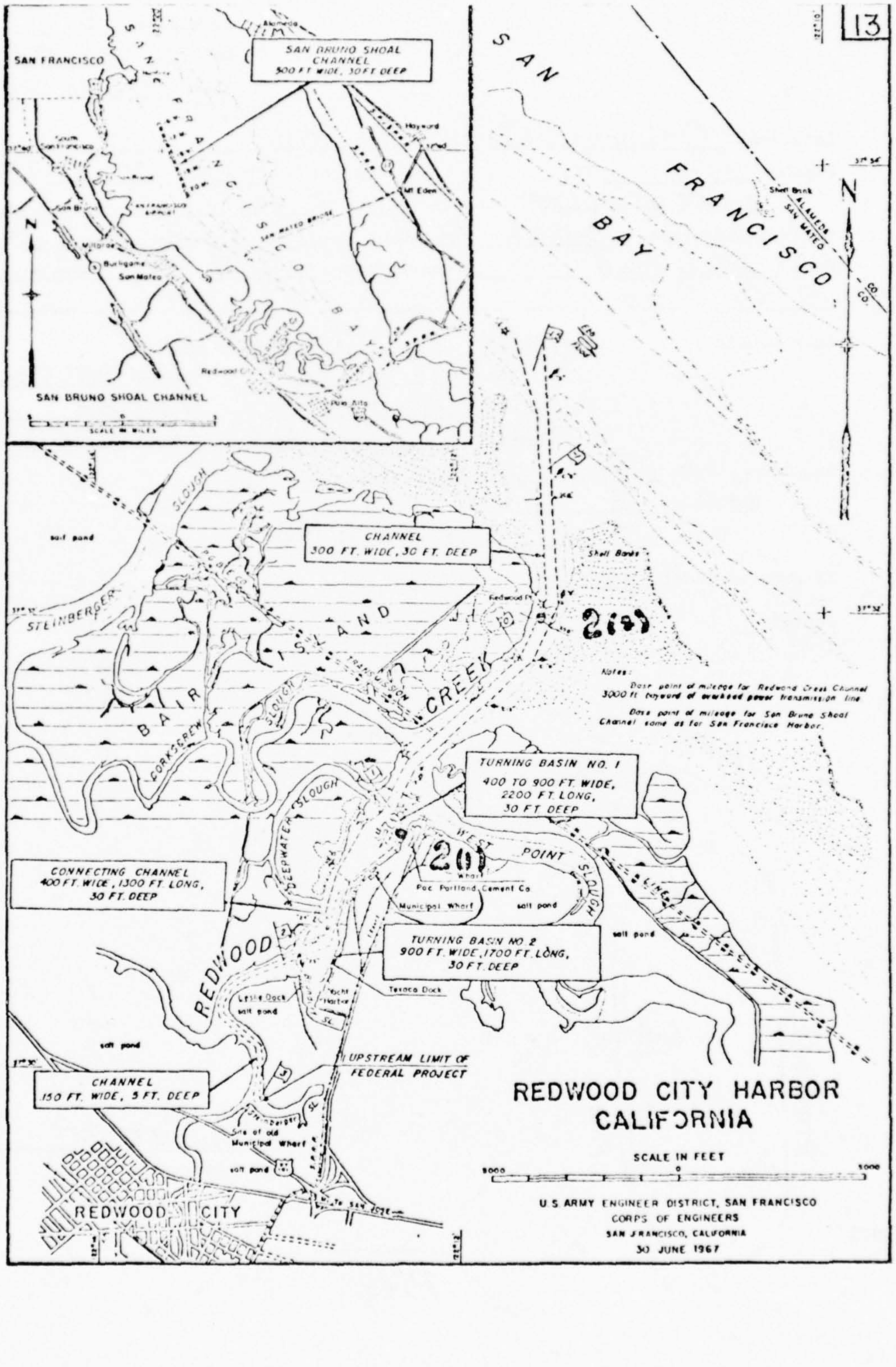
Sketch:



R. Carter
CSO LABORATORY

3/12/1973 * PVC core liner


EON COMPANY
CHART 7455-1002-G1
DEPTH IN FATHOMS


13
SAN FRANCISCO BAY
SAN BRUNO SHOAL CHANNEL 500 FT WIDE, 30 FT DEEP
SAN FRANCISCO
SAN BRUNO SHOAL CHANNEL
CHANNEL 300 FT. WIDE, 30 FT. DEEP
STEINBERGER SLOUGH
BAIR ISLAND
REDWOOD CREEK
CORKSCREW SLOUGH
Notes:
Base point of mileage for Redwood Creek Channel 3000 ft bayward of overhead power transmission line
Base point of mileage for San Bruno Shoal Channel same as for San Francisco Harbor.
TURNING BASIN NO. 1 400 TO 900 FT. WIDE, 2200 FT. LONG, 30 FT. DEEP
CONNECTING CHANNEL 400 FT. WIDE, 1300 FT. LONG, 30 FT. DEEP
DEEPWATER SLOUGH
WEST POINT SLOUGH
Pac. Portland Cement Co.
Municipal Wharf
salt pond
TURNING BASIN NO. 2 900 FT. WIDE, 1700 FT. LONG, 30 FT. DEEP
Texaco Dock
UPSTREAM LIMIT OF FEDERAL PROJECT
CHANNEL 150 FT. WIDE, 5 FT. DEEP
REDWOOD CITY
REDWOOD CITY HARBOR
CALIFORNIA
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
30 JUNE 1967

SAMPLING DATA

Sample No 3
Date 6 Dec 1973
Time 1300 to 1410

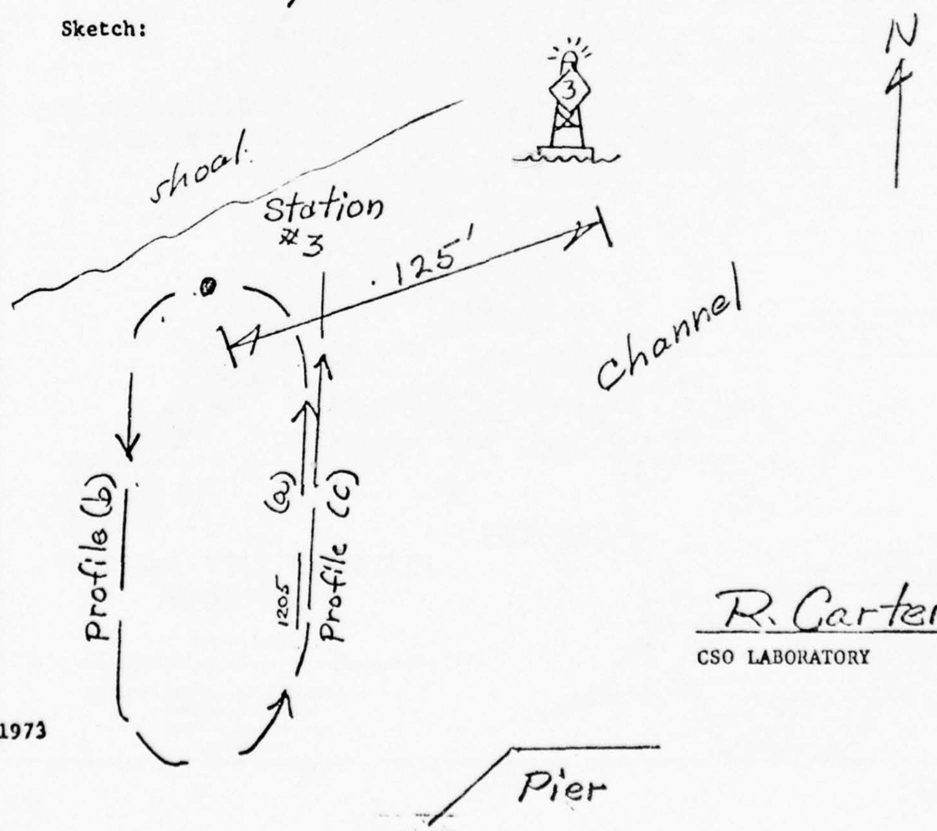
Location: Oakland Outer Harbor
Depth: 31 Ft, Tidal Condition ~1 ft at end of Ebb
30 ft @ MLLW Currents 1/2 to 3/4 k west set
General Appearance black to brownish very fine sand, silt clay
Odor Bay Mud, Penetration 115 lbs for 2 ft core.

Bulk Density: Gross Weight 4,765 gm Volume:
Tare 670 Length 75.5 cm
Net 4,095 Area 38
Density 1.43 Volume 2,860

Samples: Bulk 3a, b, & c.
Moisture 3
Other 3 and core #3

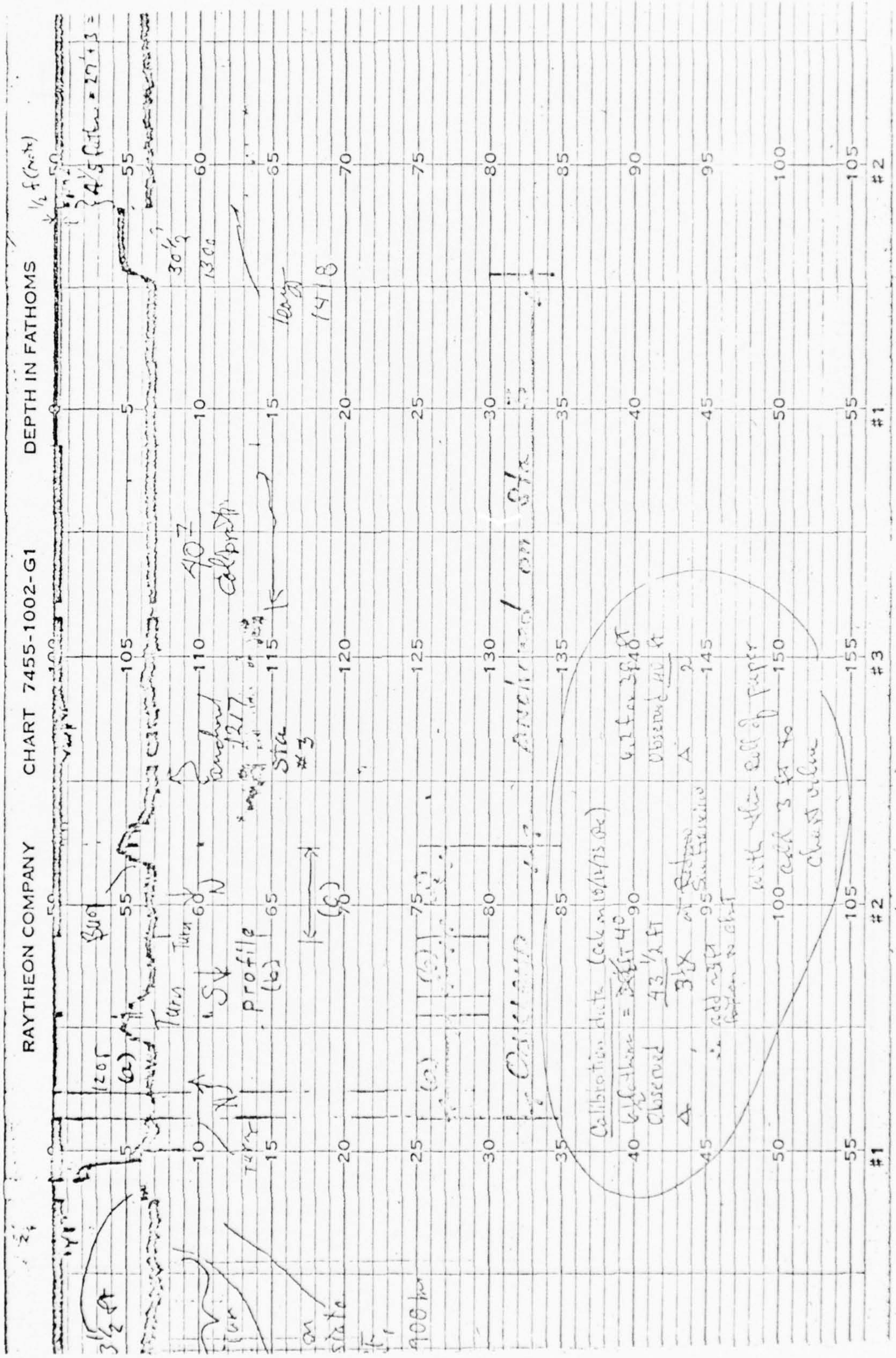
Fathometer Chart yes

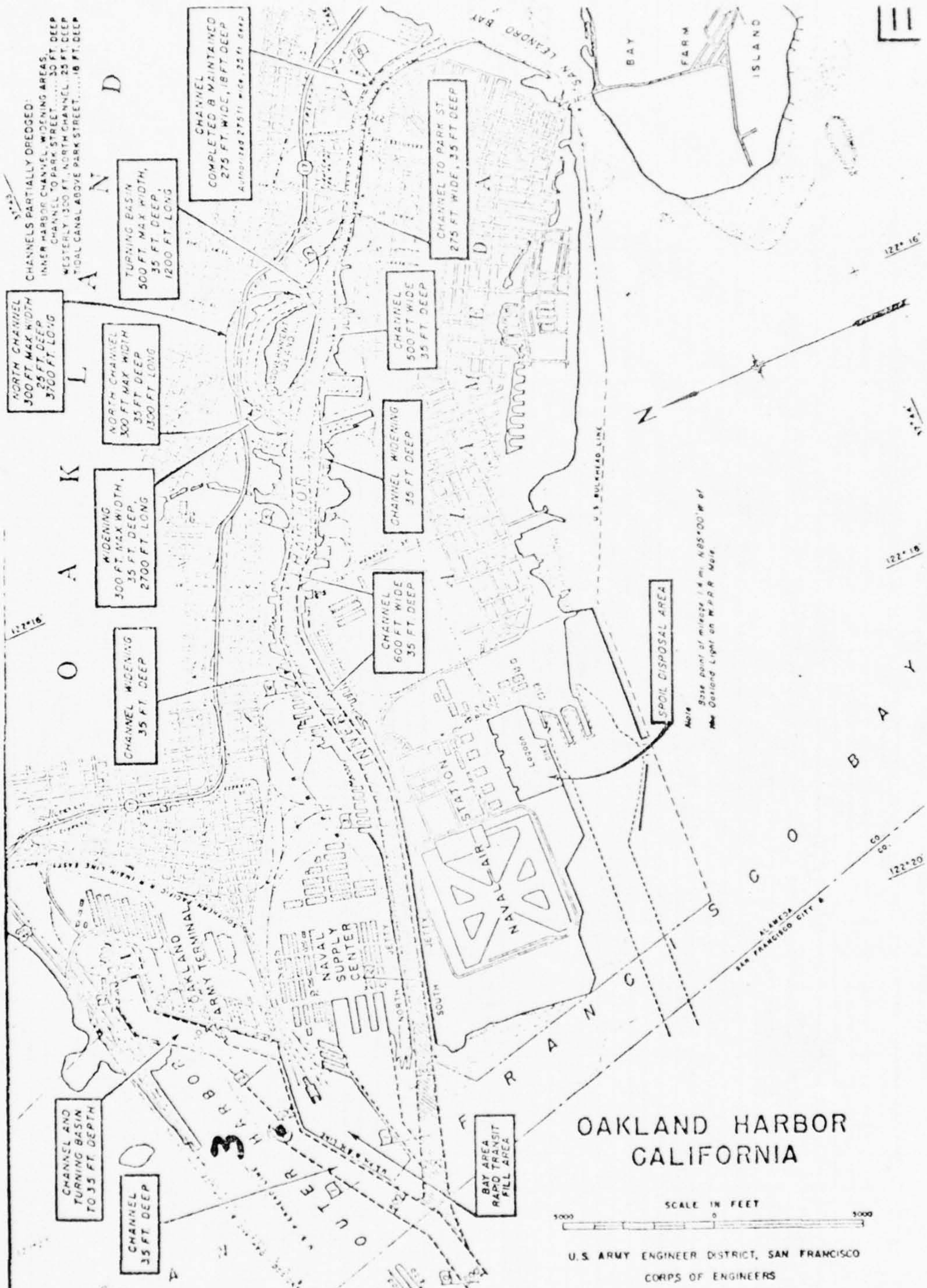
Sketch:



R. Carter
CSO LABORATORY

3/12/1973


RAYTHEON COMPANY
CHART 7455-1002-G1
DEPTH IN FATHOMS


OAKLAND HARBOR
CALIFORNIA
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
30 JUNE 1969
OAKLAND
ALAMEDA
SAN FRANCISCO BAY
CHANNEL 35 FT DEEP
CHANNEL AND TURNING BASIN TO 35 FT DEPTH
CHANNEL WIDENING 35 FT DEEP
WIDENING 300 FT MAX WIDTH, 35 FT DEEP, 2700 FT LONG
NORTH CHANNEL 300 FT MAX WIDTH 35 FT DEEP 1300 FT LONG
NORTH CHANNEL 300 FT MAX WIDTH 25 FT DEEP 3700 FT LONG
TURNING BASIN 500 FT MAX WIDTH, 35 FT DEEP, 1200 FT LONG
CHANNEL COMPLETED & MAINTAINED 275 FT WIDE, 18 FT DEEP
CHANNELS PARTIALLY DREDGED:
CHANNEL TO PARK ST. 275 FT WIDE, 35 FT DEEP
CHANNEL 500 FT WIDE 35 FT DEEP
CHANNEL WIDENING 35 FT DEEP
CHANNEL 600 FT WIDE 35 FT DEEP
SPOIL DISPOSAL AREA
BAY AREA RAPID TRANSIT FILL AREA
OAKLAND ARMY TERMINAL
NAVAL SUPPLY CENTER
NAVAL AIR STATION
OUTER HARBOR
INNER HARBOR
BAY FARM ISLAND
SAN LEANDRO BAY
U.S. BULKHEAD LINE
N

SAMPLING DATA

Sample No 5

Date 10 Dec 1973

Time 0830 - 0950

Location: Richmond Harbor Entrance

Depth: 31 Ft, Tidal Condition 5.5 ft on flood

25 1/2 MLLW Currents Slack to North set @ 3/4 K

General Appearance dark gray to gray brown fine sandy silty clay

Odor Bay Mud *, Penetration 185 lb force for 2 ft core (3" diam).

Bulk Density:	Gross Weight	5,003 gm	Volume:	
	Tare	727	Length	74 cm
	Net	4,276	Area	38
	Density	1.52	Volume	2,810

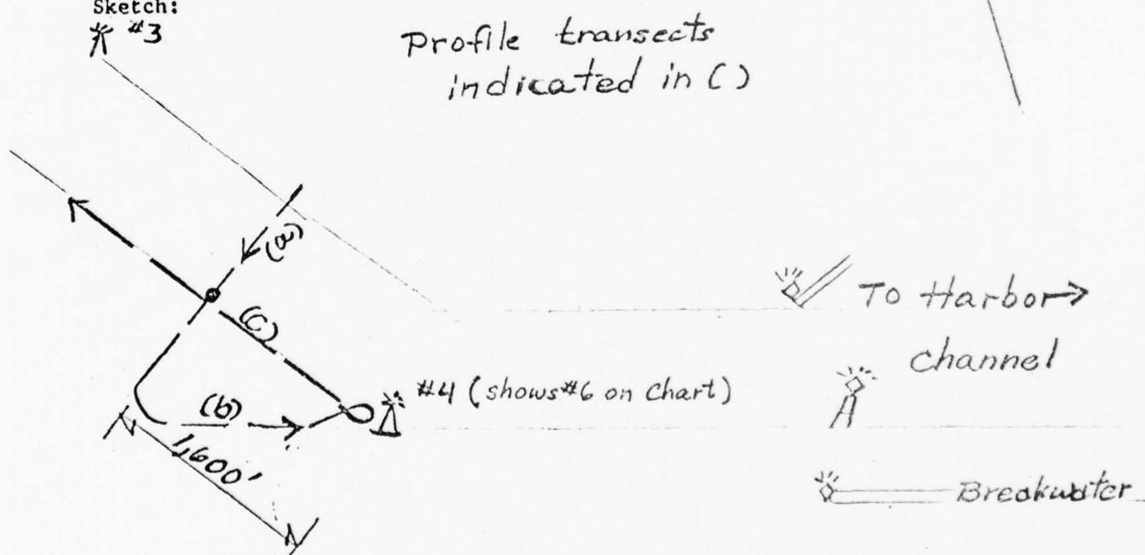
Samples: Bulk 5(a), (b), & (c).

Moisture 5

Other 2 - #5 pts and Core #5

Fathometer Chart yes

Sketch:

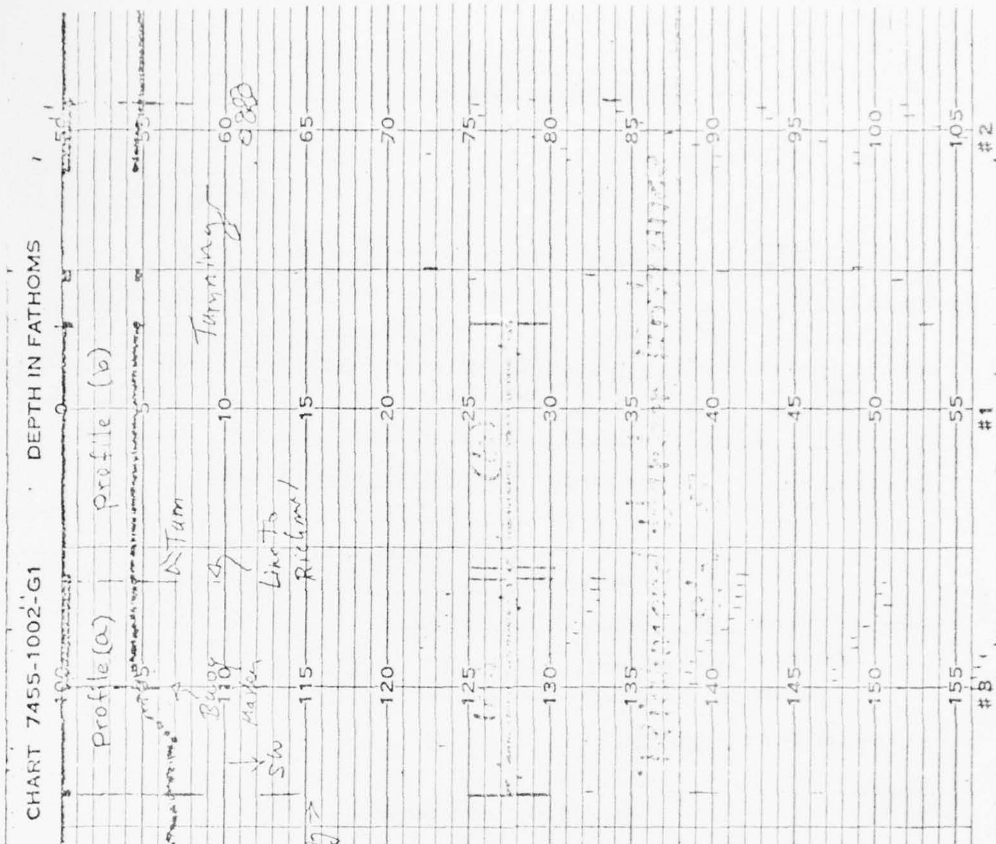


R. Carter

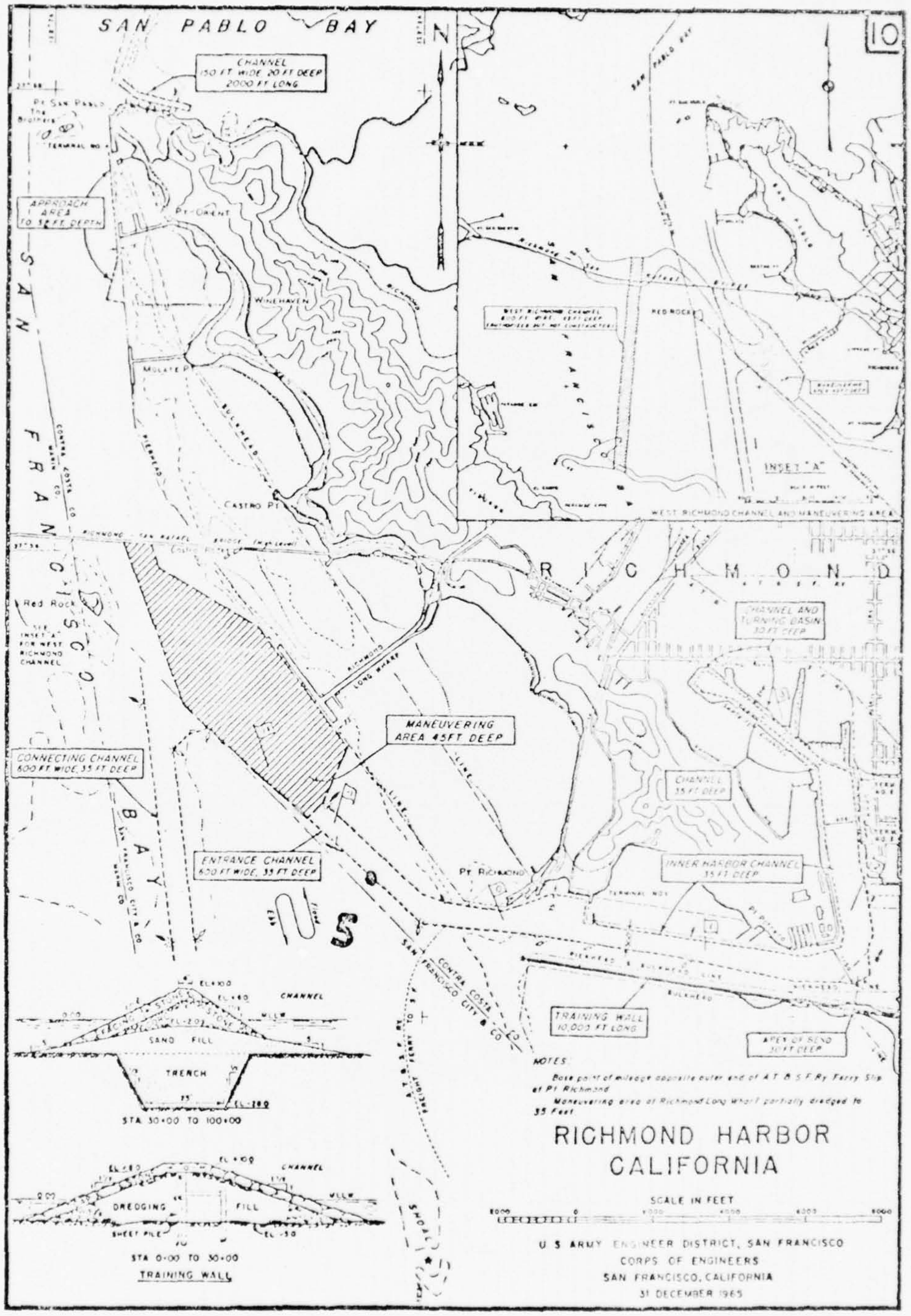
CSO LABORATORY

3/12/1973

* Bay Mud is typical esturine with no H_2S


RAYTHEON COMPANY
CHART 7455-1002-G1
DEPTH IN FATHOMS
Profile (a)
Profile (b)
Turning
Stk 2(2)
7 Dec 73
Redwood City


DEPTH IN FATHOMS
RAYTHEON COMPANY
CHART 7455-100
Profile (b)
Profile (c)


SAN PABLO BAY
CHANNEL 150 FT WIDE 20 FT DEEP 2000 FT LONG
APPROACH AREA TO 32 FT DEPTH
Pt. Orient
Winehaven
Molate Pt.
BULKHEAD
Castro Pt.
SAN FRANCISCO
Red Rock
RICHMOND
CHANNEL AND TURNING BASIN 30 FT DEEP
MANEUVERING AREA 45 FT DEEP
CONNECTING CHANNEL 600 FT WIDE, 35 FT DEEP
CHANNEL 35 FT DEEP
INNER HARBOR CHANNEL 35 FT DEEP
ENTRANCE CHANNEL 600 FT WIDE, 35 FT DEEP
Pt. Richmond
BAY
TRAINING WALL 10,000 FT LONG
APEX OF BEND 30 FT DEEP
INSET "A"
WEST RICHMOND CHANNEL AND MANEUVERING AREA
SAND FILL
TRENCH
STA 30+00 TO 100+00
DREDGING
FILL
SHEET PILE
STA 0+00 TO 30+00
TRAINING WALL
NOTES:
Base point of mileage opposite outer end of A.T. & S.F. Ry. Ferry Slip at Pt. Richmond.
Maneuvering area at Richmond Long Wharf partially dredged to 35 Feet.
RICHMOND HARBOR
CALIFORNIA
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
31 DECEMBER 1965

SAMPLING DATA

Sample No 7
Date 10 Dec 1973
Time 1055-1158

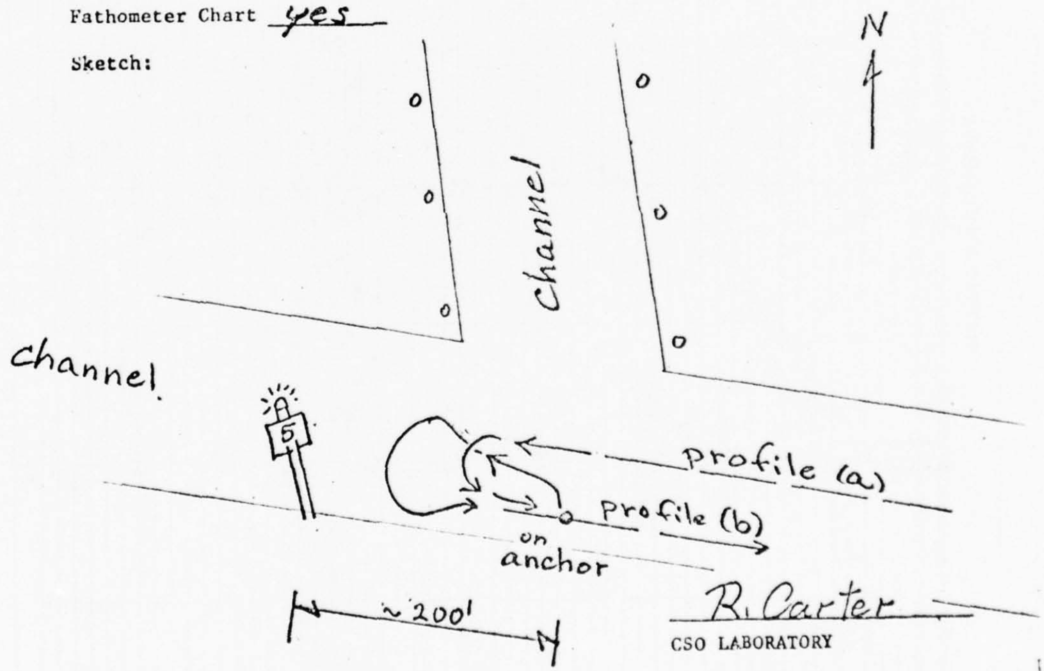
Location: San Rafael Channel
Depth: 11 to 12 Ft, 5 ft @ MLLW
Tidal Condition 6 3/4' @ HHW
Currents slack
General Appearance dark gray to brown silty clay
Odor Bay Mud, Penetration 185 lbs to penetrate 2 ft.

Bulk Density:			
Gross Weight	4,205 gm	Volume:	
Tare	726	Length	66cm
Net	3,479	Area	38
Density	1.39	Volume	2,500

Samples: Bulk 7(a), (b), & c.
Moisture 7
Other 2-#7 Core #7

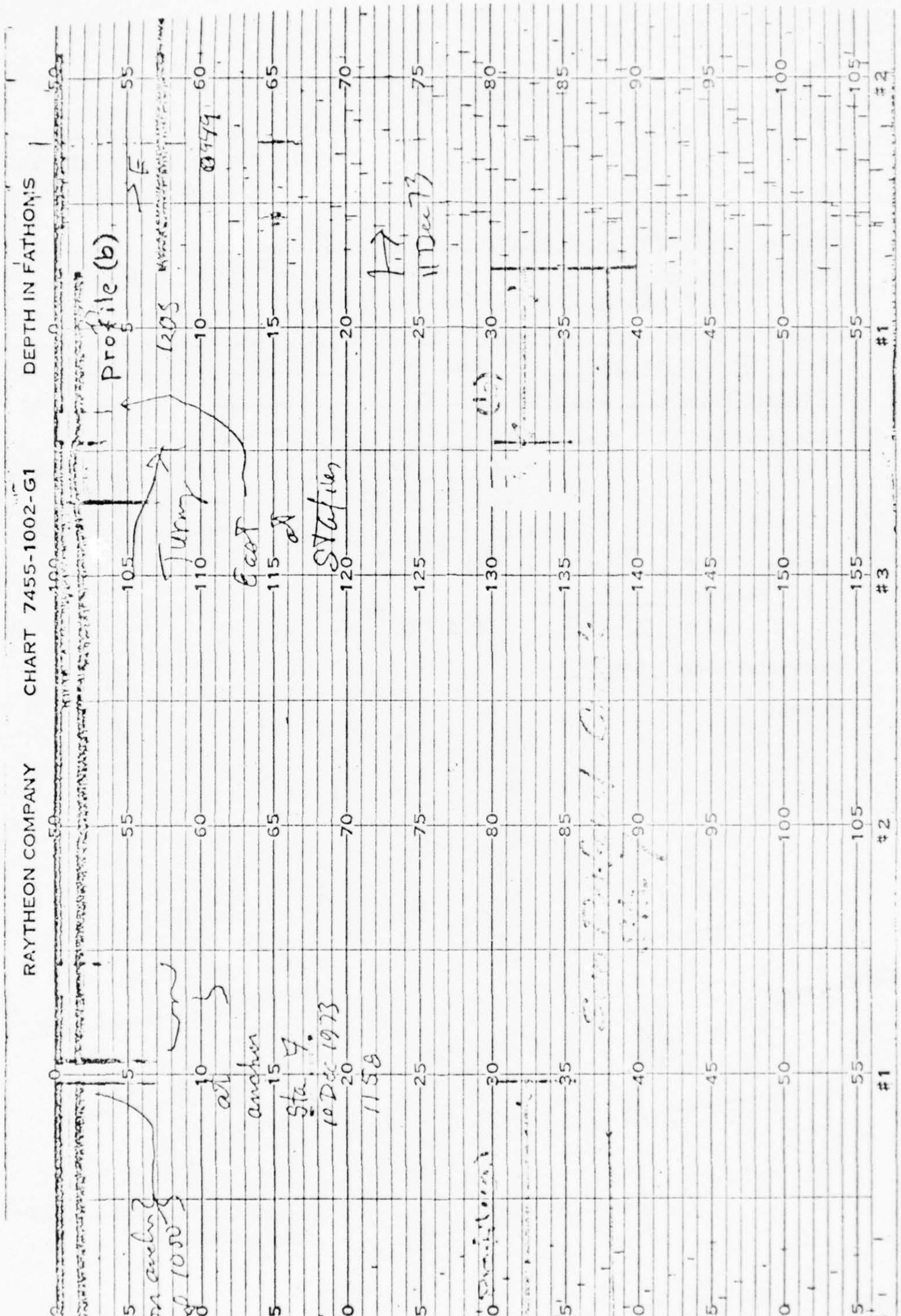
Fathometer Chart yes

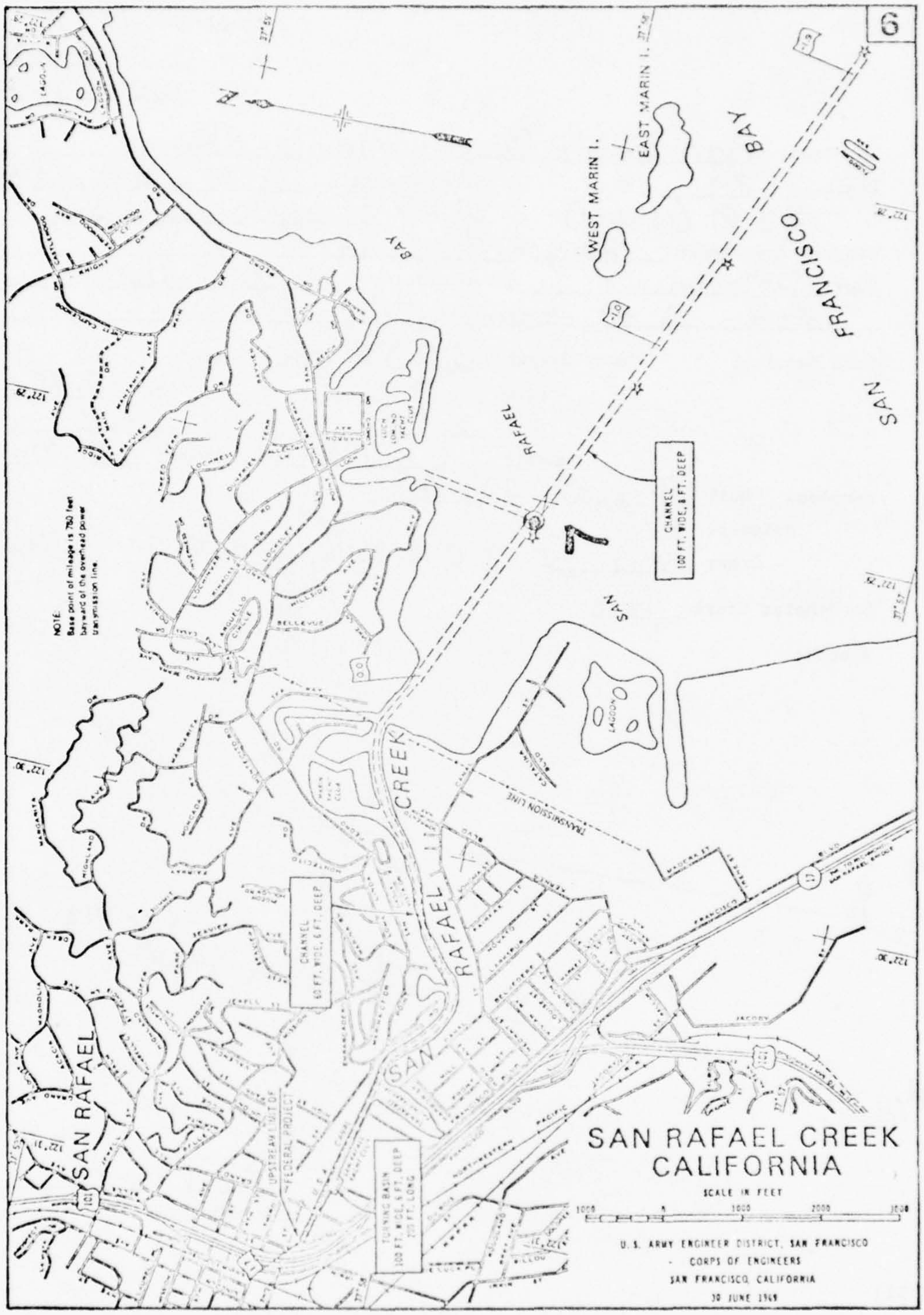
Sketch:



R. Carter
CSO LABORATORY

3/12/1973


RAYTHEON COMPANY
CHART 7455-1002-G1
DEPTH IN FATHOMS
Profile (b)
1205
11 Dec 73
Sta 7.
10 Dec 1973
1158


6
SAN FRANCISCO BAY
WEST MARIN I.
EAST MARIN I.
SAN RAFAEL BAY
CHANNEL 100 FT. WIDE, 8 FT. DEEP
SAN RAFAEL CREEK
TRANSMISSION LINE
LAGOON
CHANNEL 60 FT. WIDE, 6 FT. DEEP
UPSTREAM LIMIT OF FEDERAL PROJECT
TURNING BASIN 100 FT. WIDE, 6 FT. DEEP 200 FT. LONG
SAN RAFAEL
SAN RAFAEL CREEK
CALIFORNIA
SCALE IN FEET
U. S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
30 JUNE 1969

SAMPLING DATA

Sample No 8 (1)

Date 11 Dec 1973

Time 1410 → 1630

Location: San Pablo Bay – Pinole Shoal

Depth: 39 Ft, Tidal Condition 6 ft start of Ebb

33 ft (MLLW) Currents Slack to west set

General Appearance Brownish sand

Odor Petroleum, Penetration 300 lbs + for 2 ft penetration

Bulk Density: Gross Weight 3,252 gm. Volume:

Tare 710 Length 40.75 cm

Net 2,542 Area 38

Density 1.64 Volume 1,550

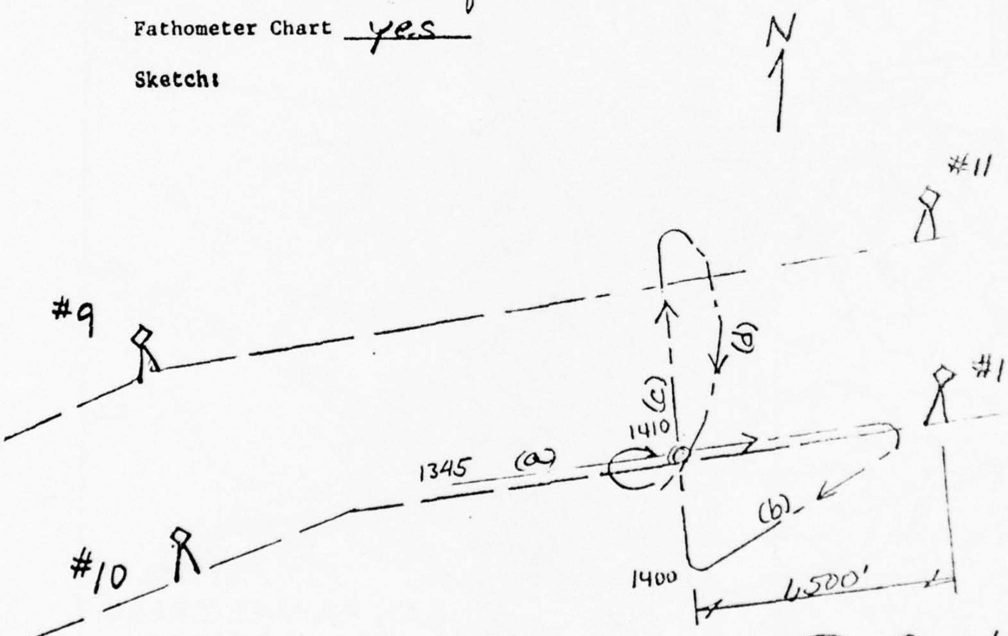
Samples: Bulk 8(1) (a), (b), & (c).

Moisture 8(1)

Other 8(1) qt, 25 lb bulk, and core # 8(1)

Fathometer Chart yes

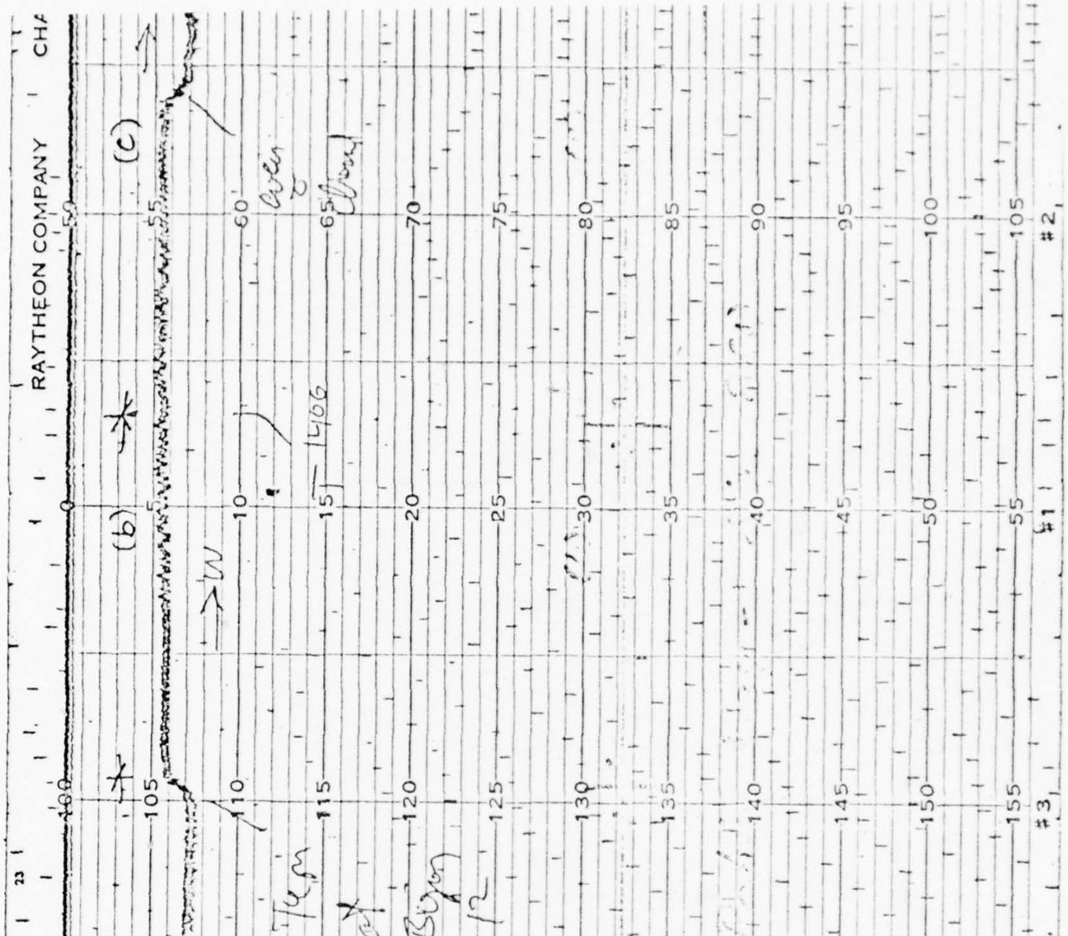
Sketch:

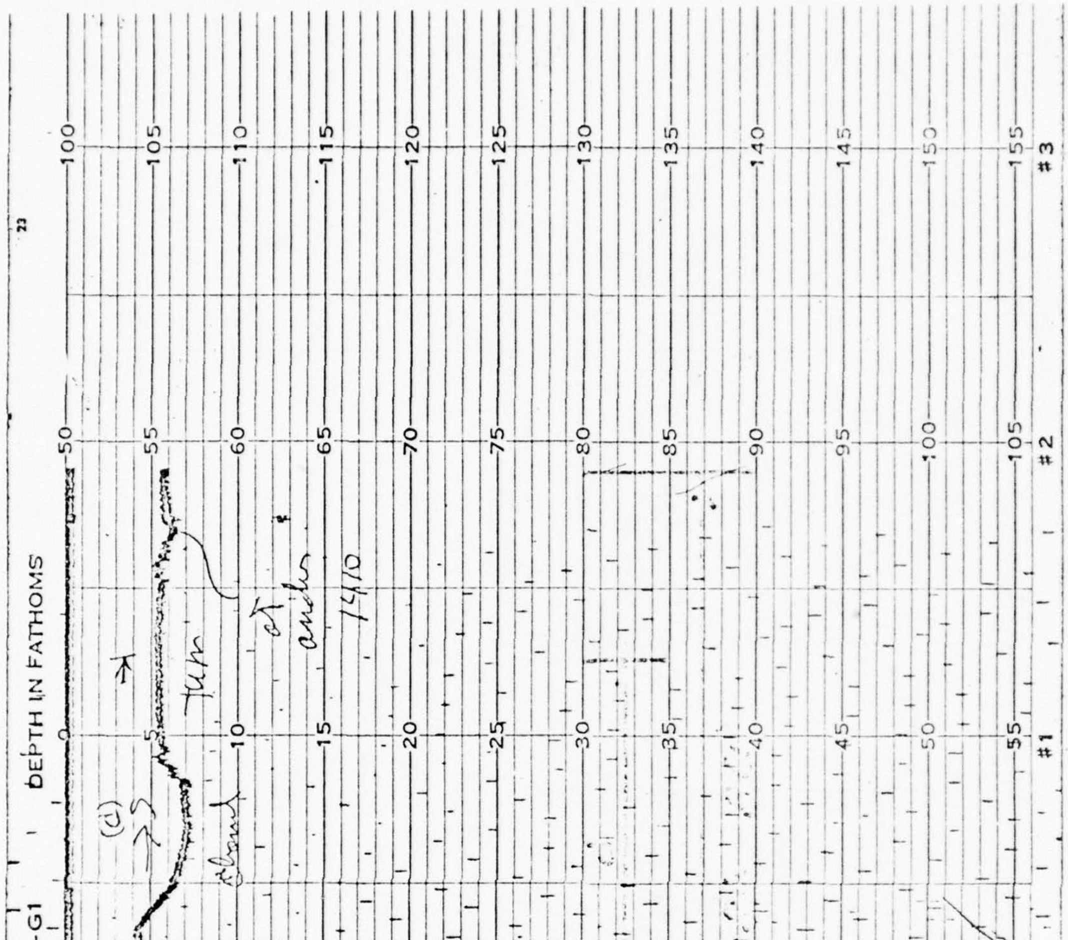


R. Carter

CSO LABORATORY

3/12/1973


DEPTH IN FATHOMS
RAYTHEON COMPANY
Profile (a)
(b)
(c)


RAYTHEON COMPANY
CHART 7455-1002-G1
DEPTH IN FATHOMS
(C)
(D)
Turn
Turn
End
at anchor
1406
1410

SAMPLING DATA

Sample No 8 (2)
Date 11 Dec 1973
Time 1120 — 1315

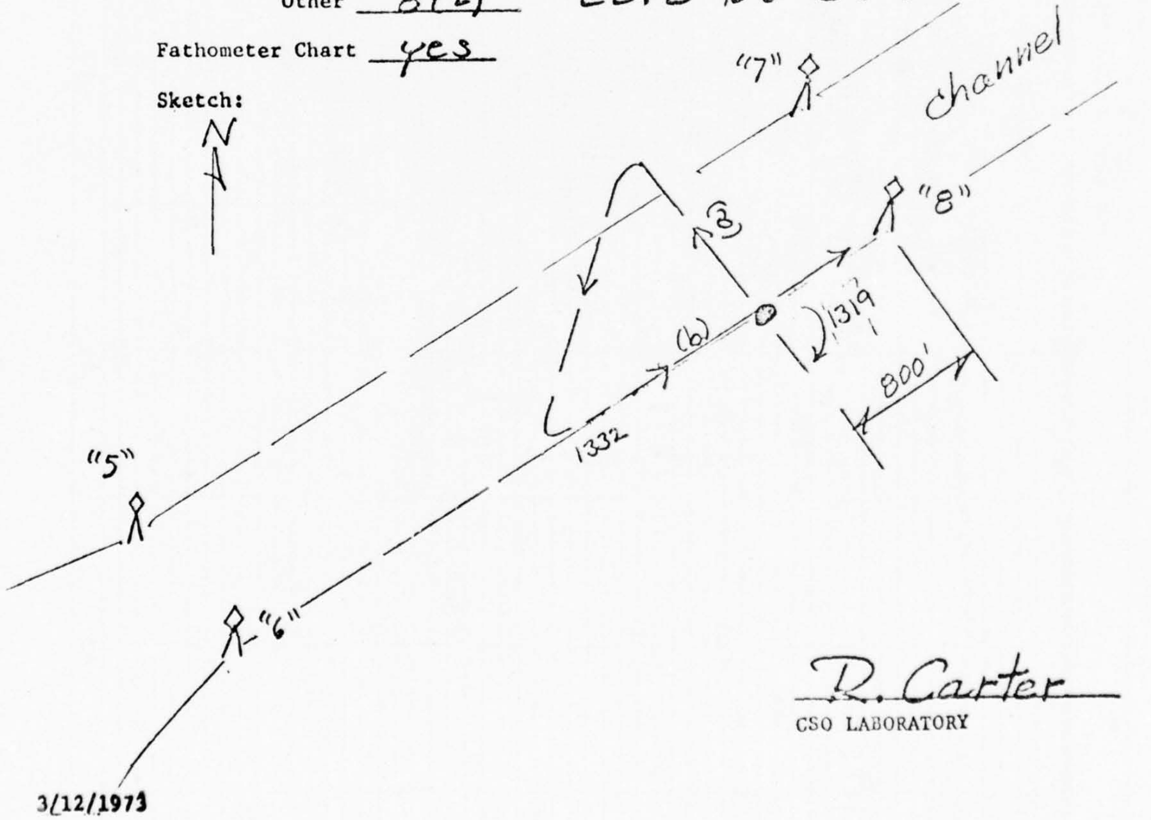
Location: San Pablo Bay - Pinole Shoal
Depth: 39 Ft, Tidal Condition End of flood to HHW
32 ft (MLLW) Currents >1 k set to east
General Appearance Gray brown Silty Sand to course sand
Odor Bay Mud, Penetration 300 lb + To penetrate 2 ft.

Bulk Density: Gross Weight 2,558 gm Volume:
Tare 725 Length 29 1/2 cm
Net 1,833 Area 38
Density 1.64 Volume 1,120

Samples: Bulk 8(2) (a), (b), & (c).
Moisture 8 (2)
Other 8(2) Core No 8 (2)

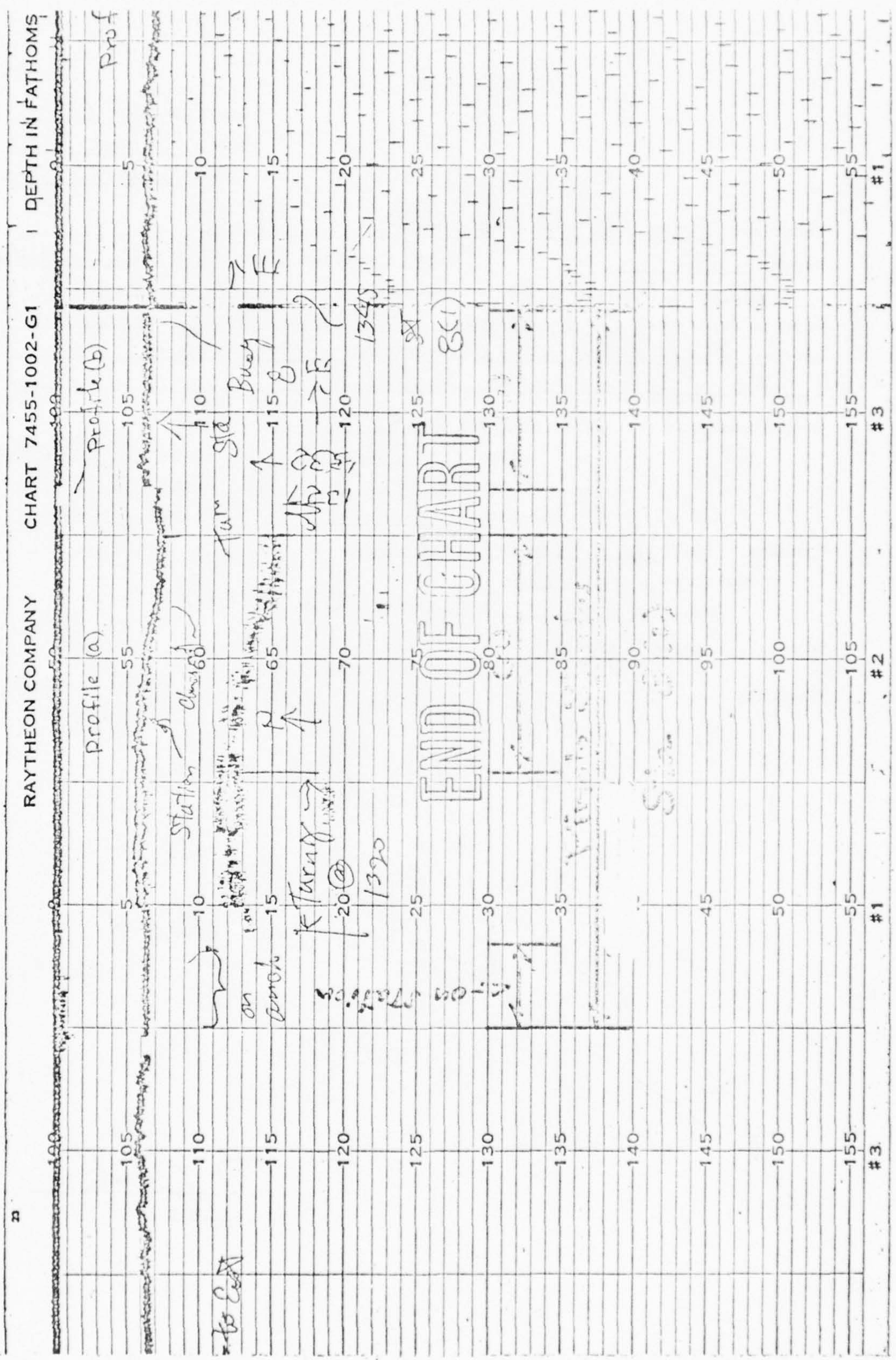
Fathometer Chart yes

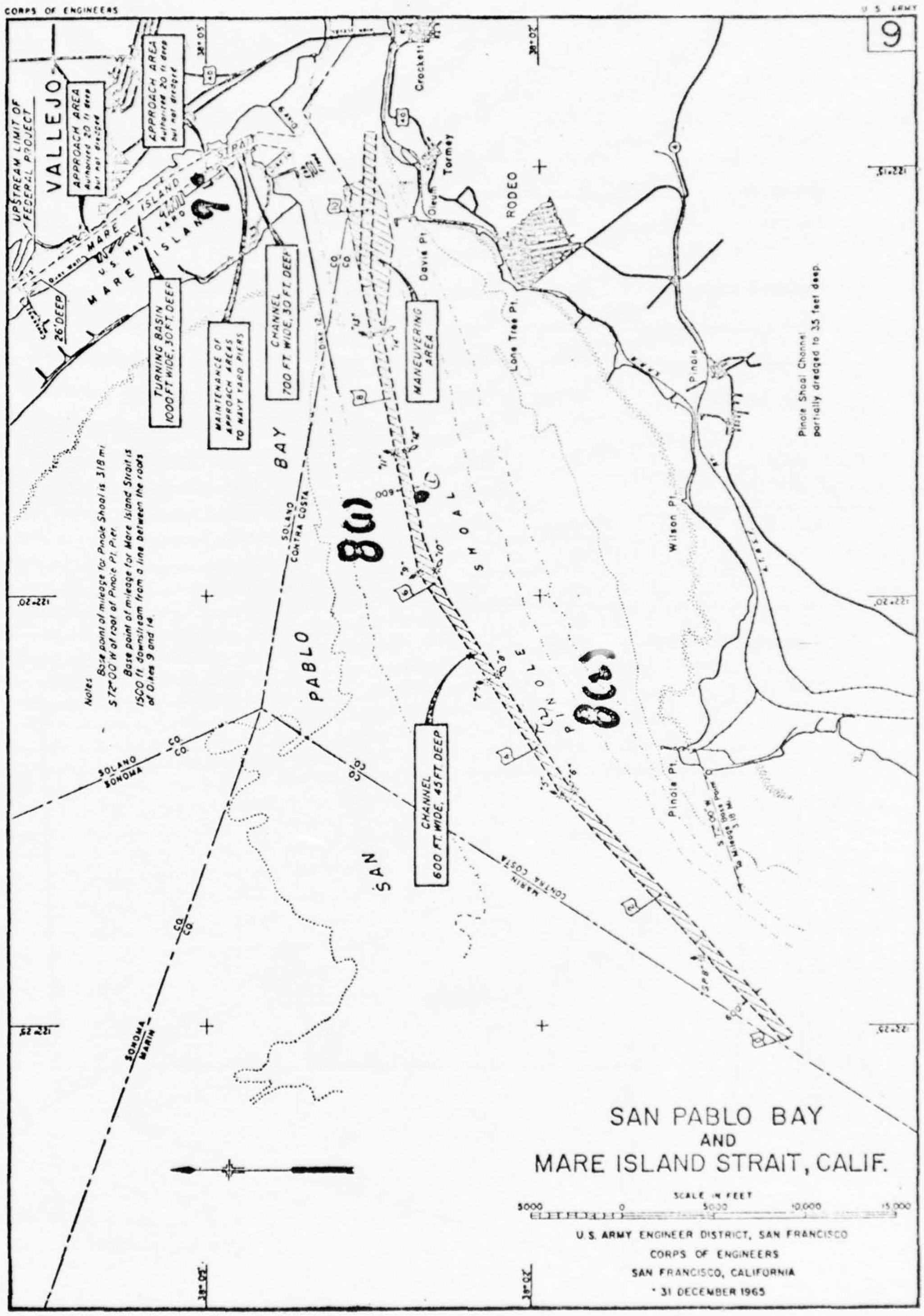
Sketch:



R. Carter
CSO LABORATORY

3/12/1973


RAYTHEON COMPANY
CHART 7455-1002-G1
DEPTH IN FATHOMS
END OF CHART
Profile (a)
Profile (b)


CORPS OF ENGINEERS
U.S. ARMY
9
SAN PABLO BAY
AND
MARE ISLAND STRAIT, CALIF.
SCALE IN FEET
5000 0 5000 10,000 15,000
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
31 DECEMBER 1965
VALLEJO
UPSTREAM LIMIT OF FEDERAL PROJECT
APPROACH AREA
MARE ISLAND
U.S. NAVY YARD
26' DEEP
TURNING BASIN 1000 FT. WIDE, 30 FT. DEEP
MAINTENANCE OF APPROACH AREAS TO NAVY YARD PIERS
CHANNEL 700 FT. WIDE, 30 FT. DEEP
MANEUVERING AREA
CHANNEL 600 FT. WIDE, 45 FT. DEEP
Crockett
Tormey
RODEO
Davis Pt.
Lone Tree Pt.
Pinole
Wilson Pt.
Pinole Pt.
PINOLE SHOAL
SAN PABLO BAY
SOLANO CO.
CONTRA COSTA CO.
SONOMA CO.
MARIN CO.
Pinole Shoal Channel partially dredged to 35 feet deep
Notes: Base point of mileage for Pinole Shoal is 3.18 mi. S72°00'W of root of Pinole Pt. Pier.
Base point of mileage for Mare Island Strait is 1500 ft. downstream from a line between the roots of Dikes 9 and 14.
8(1)
8(2)

SAMPLING DATA

Sample No 9
Date 12 Dec 1973
Time 1000-1123

Location: Mare Island Straits
Depth: 18 Ft, 14.5 ft (MLLW)
Tidal Condition 3.5 ft on flood
Currents set north 3/4 k
General Appearance Gray silty clay
Odor Bay Mud, Penetration 136 lbs for 2 ft core

Bulk Density:

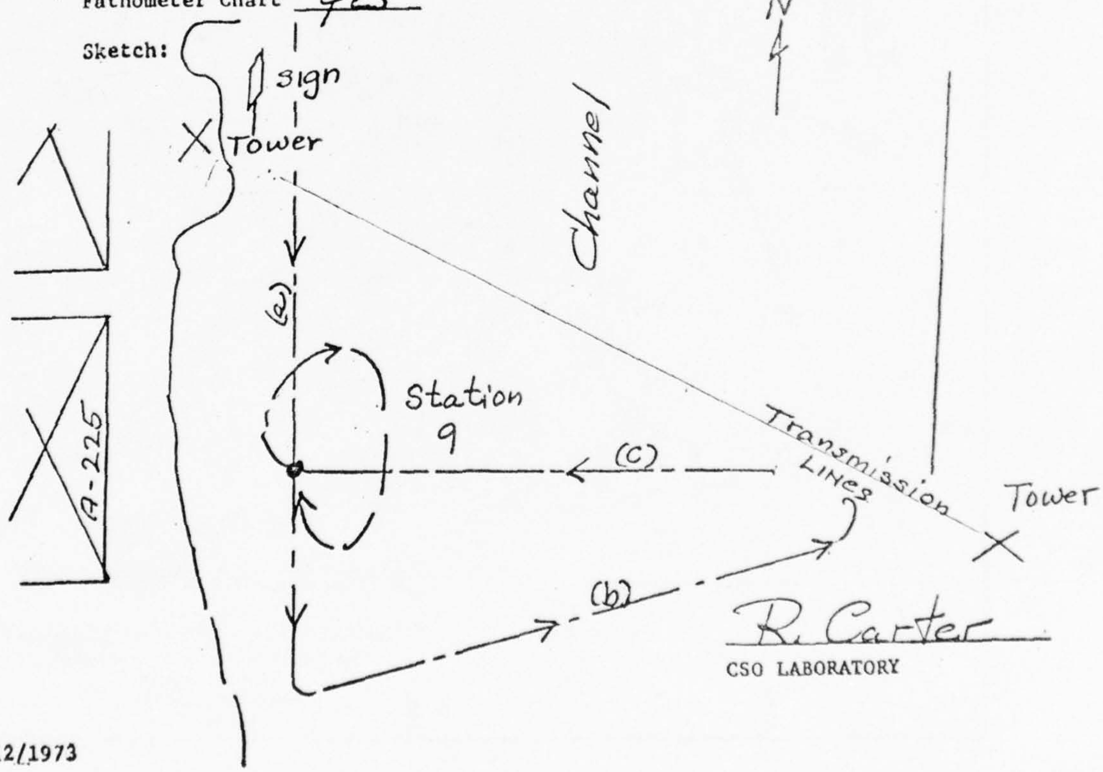
Gross Weight	4,105 gm	Volume:	
Tare	730	Length	68.5 cm
Net	3,375	Area	38
Density	1.30	Volume	2,600

Pier 21

Samples: Bulk 9(a), (b), & (c).
Moisture 9
Other 9 and core #9

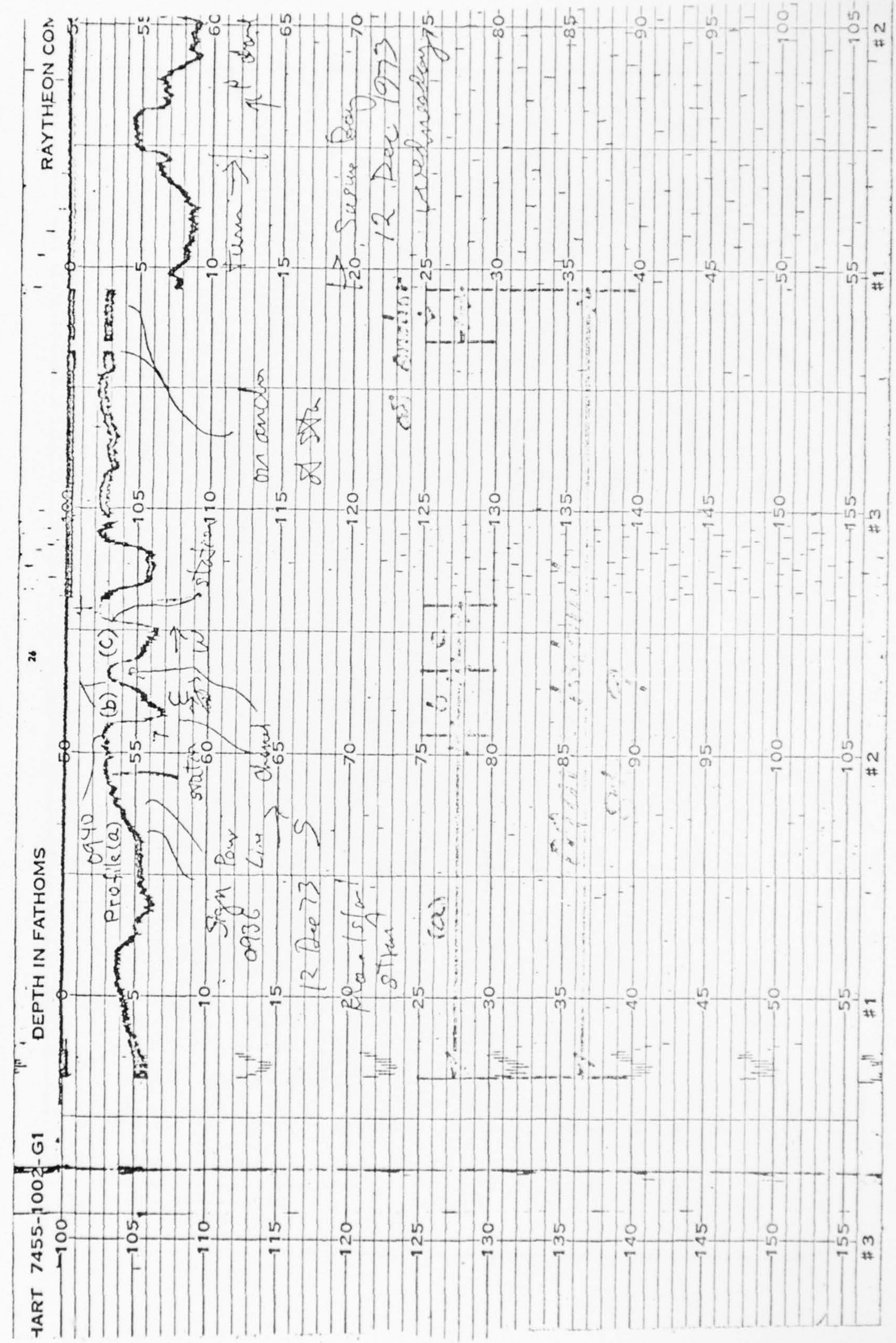
Fathometer Chart yes

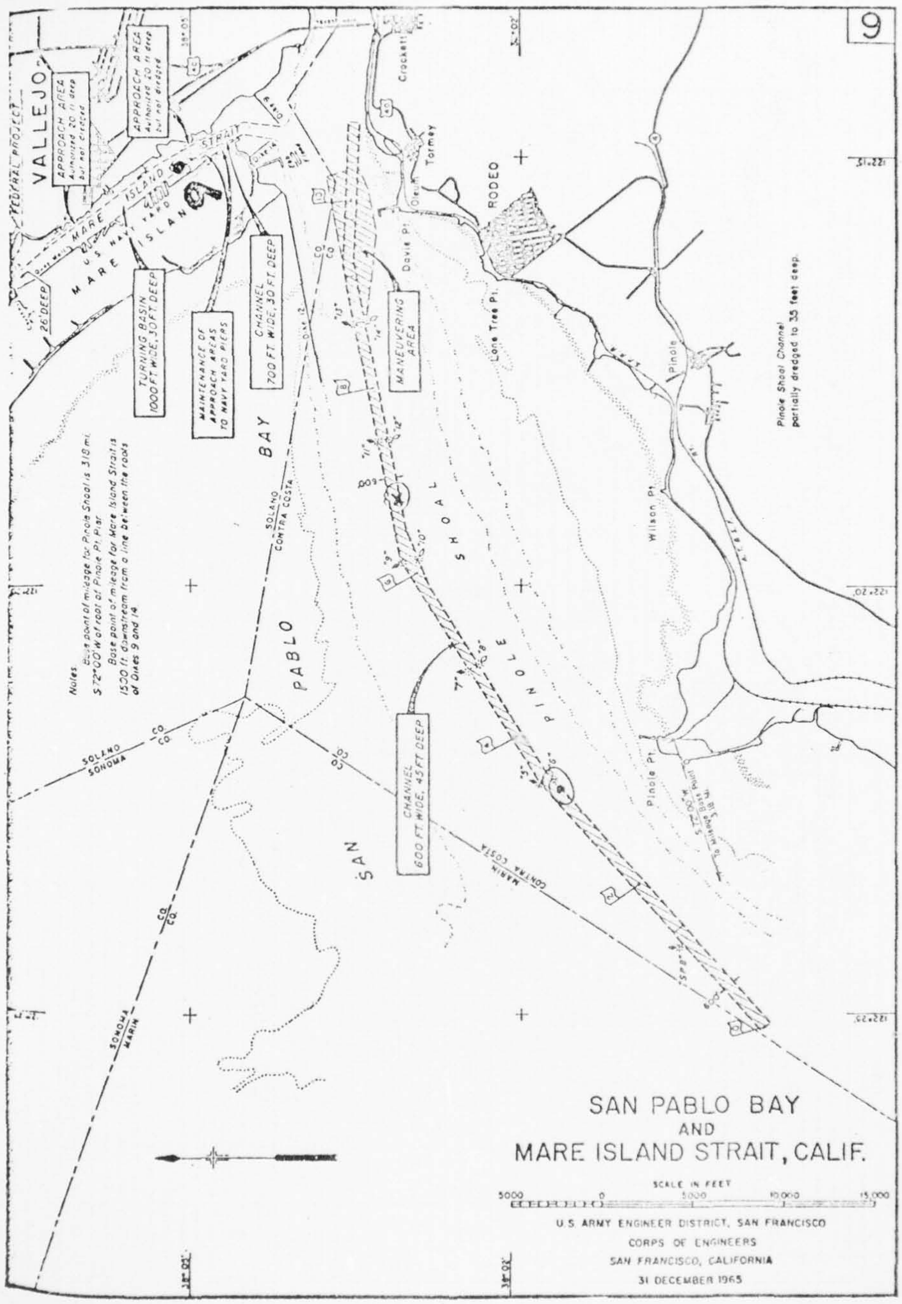
Sketch:



R. Carter
CSO LABORATORY

3/12/1973


HART 7455-1002-G1
DEPTH IN FATHOMS
RAYTHEON CON
Profile (a)
0940
(b)
(C)
12 Dec 73
12 Dec 1973


9
SAN PABLO BAY
AND
MARE ISLAND STRAIT, CALIF.
SCALE IN FEET
5000 0 5000 10,000 15,000
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
31 DECEMBER 1965

SAMPLING DATA

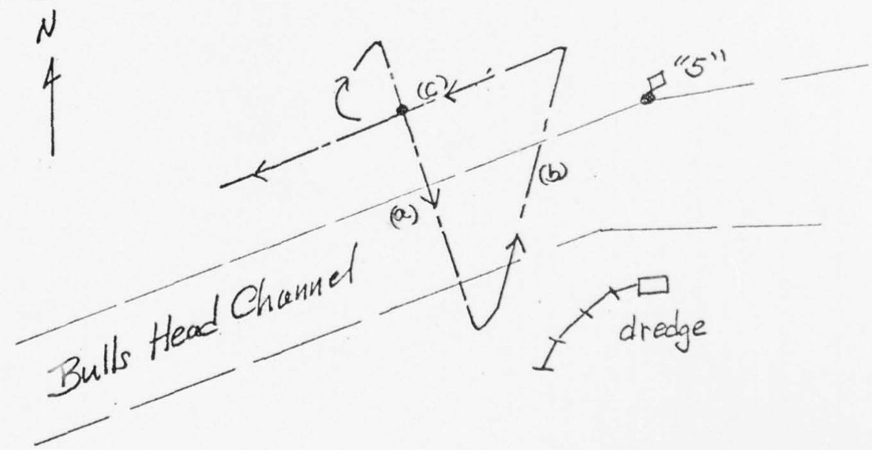
Sample No 10
Date 12 Dec 1973
Time 1440—1640

Location: Suisun Bay
Depth: 32 Ft, Tidal Condition ~ 6.2 ft near HHW
26 ft (MLLW) Currents Set East ~ 1K to slack
General Appearance Gray to brown micacious sand c̄ silt bands
Odor Bay Mud, Penetration 285 lbs for
2 ft penetration

Bulk Density: Gross Weight 3,692 gm Volume:
Tare 729 Length 47.5 cm
Net 2,963 Area 38
Density 1.64 Volume 1,800

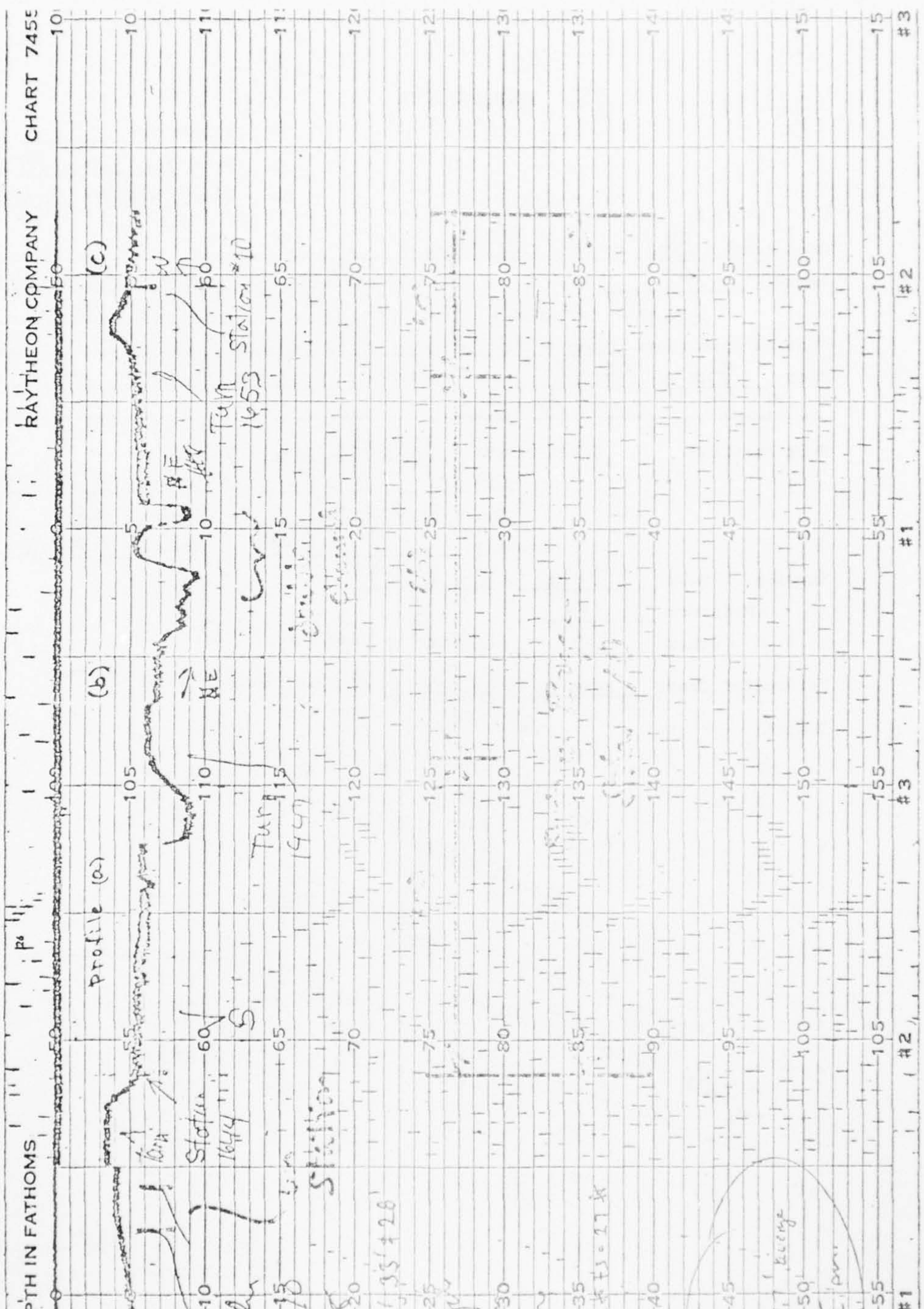
Samples: Bulk 10 (a), (b), & (c).
Moisture 10
Other 10 and Core #10
Fathometer Chart yes also core for Dr Krone

Sketch:



R. Carter
CSO LABORATORY

3/12/1973


DEPTH IN FATHOMS
RAYTHEON COMPANY
CHART 7455
Profile (a)
(b)
(c)


N38°3"
W122°6"
W122°7"
sta #10
sewer
BULLS HEAD CHANNEL
SUISUN BAY
N
BENICIA-MARTINEZ BRIDGE
1/2 Nautical Mile
0
1/2

SAMPLING DATA

Sample No 11
Date 17 Dec 1973
Time 0830 - 0930

Location: Napa River at Tulucay Cr. Inlet

Depth: 15' Ft, Tidal Condition HHW ~7 ft
8 ft at MLLW Currents Slack to 1/4 k ebb

General Appearance dark grey to brown clay silty sand *

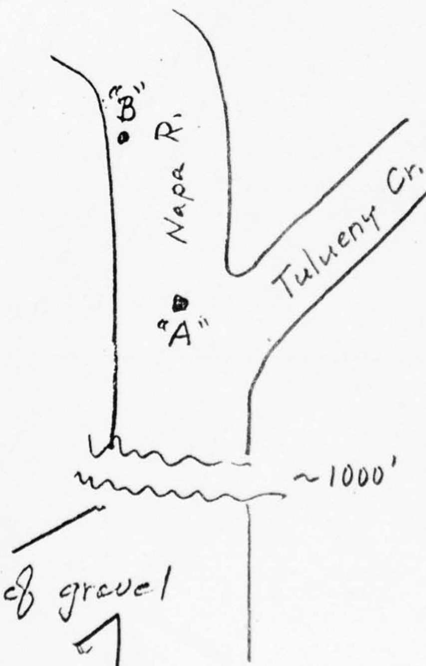
Odor sewer to none, Penetration 100 lbs
for 2 ft core

Bulk Density: Gross Weight 3,942 gm Volume:
Tare 731 Length 52 1/2 cm
Net 3,211 Area 38
Density 1.61 Volume 1,990

Samples: Bulk 11 (a), (b), & (c).
Moisture 11
Other 11 Core #11

Fathometer Chart no bottom 15' to 16' over area "A" and 14 1/2 to 15 1/2 over "B"

Sketch:

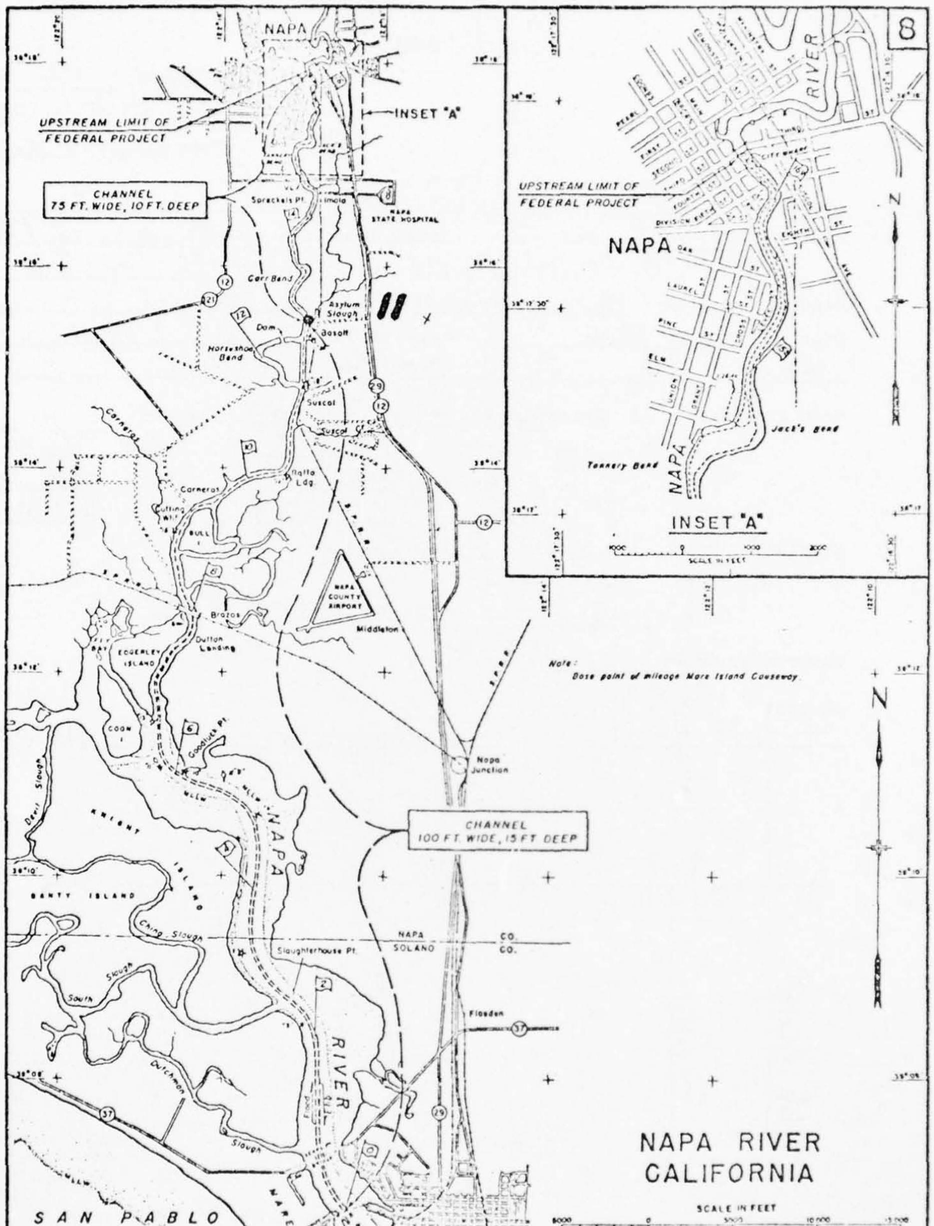


N

R. Carter
CSO LABORATORY

* lense of gravel

3/12/1973


NAPA RIVER
CALIFORNIA
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
30 JUNE 1968
8
INSET "A"
UPSTREAM LIMIT OF
FEDERAL PROJECT
CHANNEL
75 FT. WIDE, 10 FT. DEEP
CHANNEL
100 FT. WIDE, 15 FT. DEEP
NAPA
NAPA COUNTY AIRPORT
Note:
Base point of mileage Mare Island Causeway
SAN PABLO
BAY
MARE ISLAND
VALLEJO
NAPA RIVER
Jack's Bend
Tannery Bend
Napa Junction
Slaughterhouse Pt.
Middleton
Brazos
Dutton Landing
Asylum Slough
Horseshoe Bend
Carr Bend
Suscol
Cuttings Wharf
NAPA SOLANO CO. CO.

SAMPLING DATA

Sample No 12

Date 17 Dec 1973

Time 1233 - 1315

Location: Petaluma River

Depth: 14 - 15 Ft, Tidal Condition 2 ft end of Ebb

12 - 13 ft (MLLW) Currents Set south ~ 1/2 k

General Appearance Gray brown silty clay

Odor Bay Mud, Penetration 60 lbs for 2 ft core

Bulk Density:

Gross Weight	4,436 gm	Volume:	
Tare	699	Length	70.5
Net	3,737	Area	38
Density	1.39	Volume	2,680

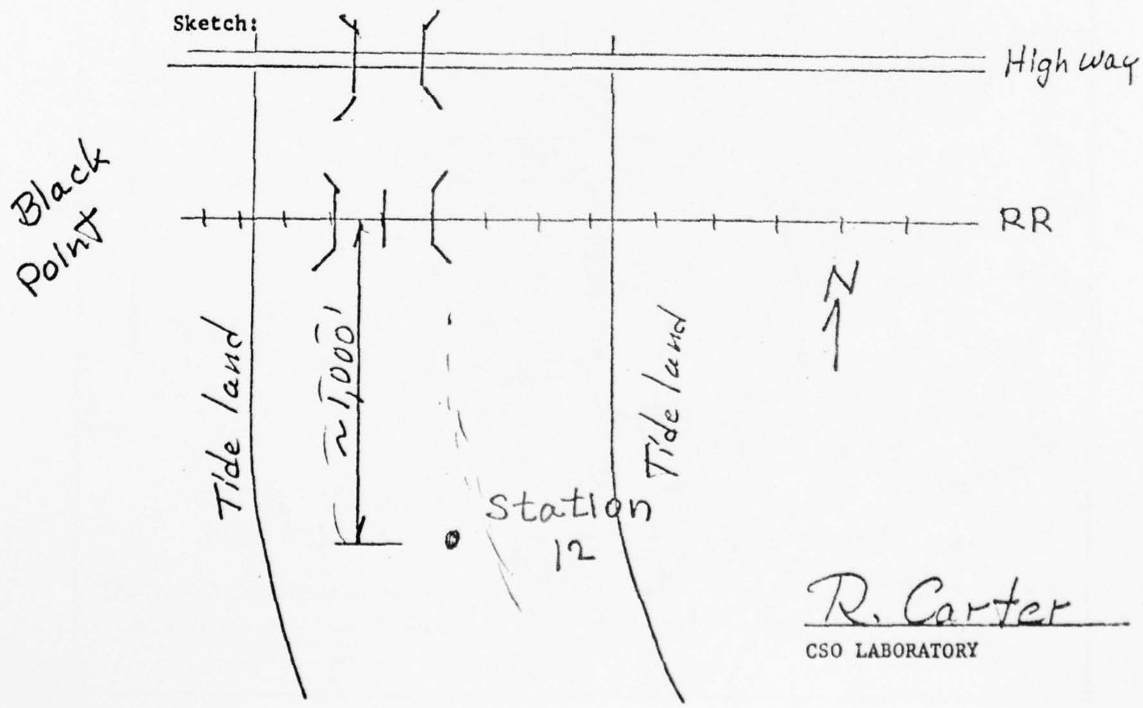
Samples: Bulk 12 (a), (b), & (c).

Moisture 12

Other 12 and core #12

Fathometer Chart no

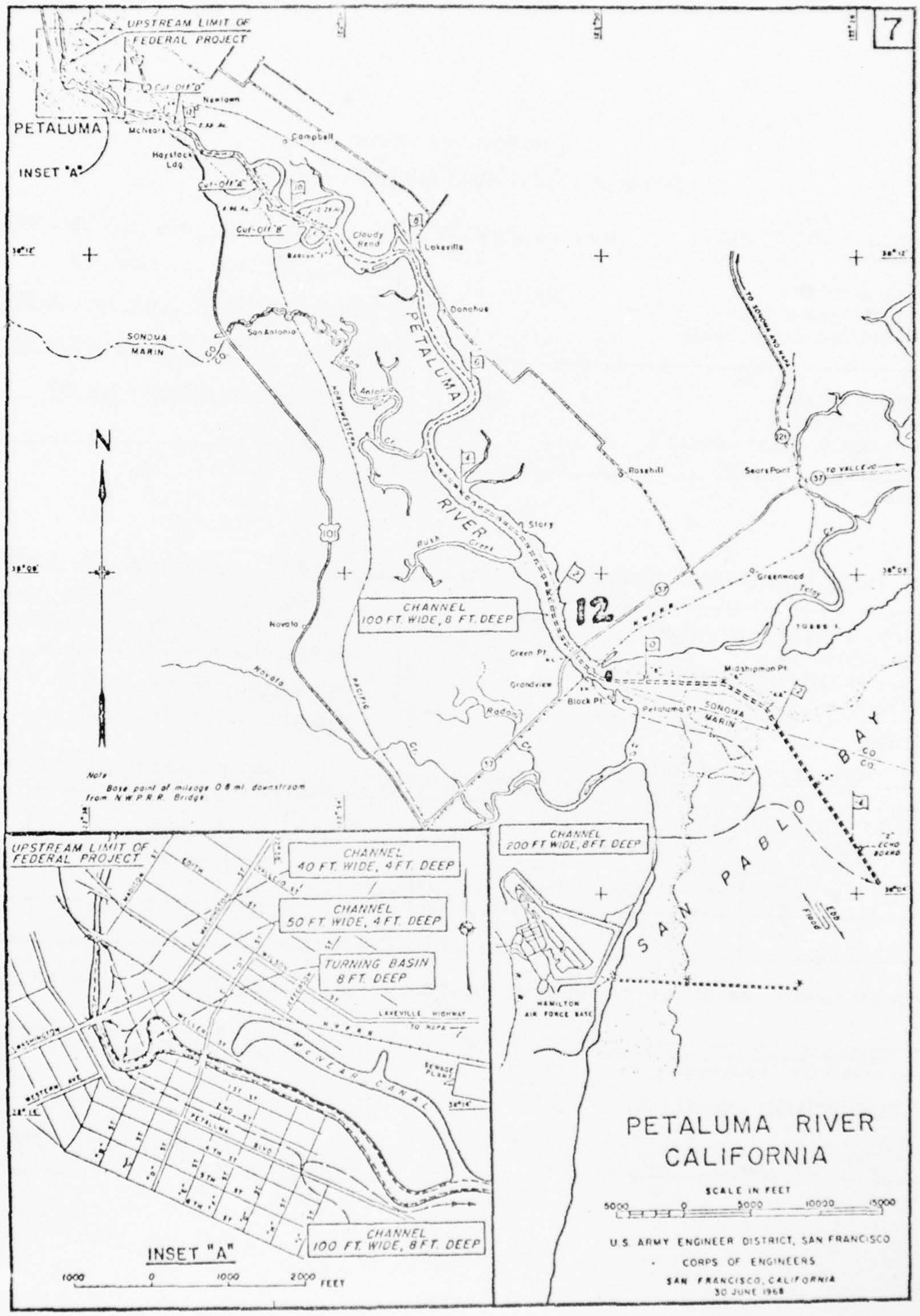
Sketch:



R. Carter

CSO LABORATORY

3/12/1973


7
UPSTREAM LIMIT OF FEDERAL PROJECT
PETALUMA
INSET "A"
PETALUMA RIVER
CHANNEL 100 FT. WIDE, 8 FT. DEEP
12
SAN PABLO BAY
SONOMA
MARIN
Novato
Lakeville
Donahue
Sears Point
Green Pt.
Black Pt.
Petaluma Pt.
Midshipman Pt.
UPSTREAM LIMIT OF FEDERAL PROJECT
CHANNEL 40 FT. WIDE, 4 FT. DEEP
CHANNEL 50 FT. WIDE, 4 FT. DEEP
TURNING BASIN 8 FT. DEEP
McNEAR CANAL
CHANNEL 100 FT. WIDE, 8 FT. DEEP
INSET "A"
CHANNEL 200 FT. WIDE, 8 FT. DEEP
HAMILTON AIR FORCE BASE
PETALUMA RIVER CALIFORNIA
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA
30 JUNE 1968

2/124

REPORT OF TESTS

SHIPPED BY: TRENT TUBE DIVISION — CRUCIBLE INC

CUST. ORDER NO. 77401A SHIP FROM EAST TROY WIS ON MILL ORD. NO. E5-80095-2-2

SOLD TO
DUHIG & CO INC
5071 TELEGRAPH ROAD
LOS ANGELES CALIF 90022

SHIP TO
DUHIG & CO INC
2997 TEA GARDEN ST
SAN LEANDRO CALIF 94577

FT. 560 PCS. 28

SHIP DATE 5/11/72 B/L NO. E 007556-03

ROUTING Motor Transport c/o Universal Carloading at Milwaukee - PPD

MARKS:

MFG. BY: TRENT TUBE DIVISION CRUCIBLE INC AT EAST TROY WIS ON ORDER NO. E5-800950202

DESCRIPTION
3.000" x .065" x 20 ' RML
FULL FINISH BA
TRENTWELD STAINLESS TEEL TUBING
A-269-69

MADE FROM HEAT NO. 132124

NON-DESTRUCTIVE TESTING

PRESSURE: AIR ☐ HYDRO ☐ ____ PSI

EDDY CURRENT TEST ☒

RADIOGRAPHIC TEST ☐

GRADE: 316

CHEMICAL ANALYSIS

C	MN	P	S	SI	NI	CR	MO	TI	CU	CO					
.05	1.65	.037	.018	.60	13.21	17.53	2.31								

MECHANICAL TESTS

TENSILE STRENGTH PSI	YIELD STRENGTH PSI	ELONG. 2"	HARDNESS	FLANGE	FLAT	FLARE	REV. FLAT	REV. BEND	GRAIN SIZE	
			RB75/76	OK		OK	OK			

CORROSION TESTS: ACIDIFIED COPPER SULPHATE ____ NITRIC-HF ____ NITRIC ____

WE HEREBY CERTIFY THIS REPORT TO BE TRUE AND CORRECT ACCORDING TO RECORDS IN POSSESSION OF THIS CORPORATION.

TRENT TUBE DIVISION — CRUCIBLE INC

SIGNED: Malcolm H. Weeks

SWORN TO AND SUBSCRIBED BEFORE ME

THIS 15th DAY OF MAY 19 72

2/25/73 Clara L. Mitchell

MY COMMISSION EXPIRES NOTARY

APPENDIX B

CHEMICAL ANALYSES OF SEDIMENTS AND ELUTRIATES

APPENDIX B

CHEMICAL TESTINGS OF SEDIMENTS AND ELUTRIATES

1. Environmental Quality Analysts Inc. (EQA) Letter of January 24, 1974

Sediment Analyses

Table 1: Sediment Analyses by EPA Methods

Table 2: Metals Analyses on Tapwater Elutriate

Table 3: Other Analyses on Tapwater Elutriate

Table 4: Metals Analyses on Seawater Elutriate

Table 5: Other Analyses on Seawater Elutriate

2. EQA Letter of February 12, 1974

Organohalogen Determination on Elutriates

Table 1: Tapwater Elutriates

Table 2: Seawater Elutriates

3. EQA Letter of February 20, 1974

Exchangeable Bases, Sediment Samples

ENVIRONMENTAL
QUALITY
ANALYSTS
INC.

A DIVISION OF BROWN AND CALDWELL
SAN FRANCISCO ALHAMBRA

J. T. NORGAARD, P.E. 6821C President
T. V. LUTGE, P.E. 9219C Vice-President
M. L. WHITT, P.E. 15118C General Manager
M. N. LIPSCHUETZ Technical Director
R. D. SMITH Senior Oceanographer
J. B. TYLER Laboratories
C. P. WALTON, Ph.D. Water Chemist

January 24, 1974

L100H

Mr. Ray B. Krone
645 Coolidge Street
Davis, California

SEDIMENT ANALYSES, INTERNATIONAL ENGINEERING COMPANY

We have completed the work requested by you on the group of sediment samples submitted by International Engineering Company December 7-17, 1973, and our results are tabulated below. Explanatory footnotes follow each table, and discussion follows Table 5.

Table 1

Sediment Analyses by EPA Methods
All results expressed as mg/kg dry weight

Lab No.	Sample Location	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Zinc (Zn)	Oil and Grease
20475	Bottom Sediment, San Francisco	1.59	0.56	58	106	8400
20476	Bottom Sediment, (1) Redwood City	3.78	0.54	113	190	9200
20477	Bottom Sediment, (2) Redwood City	2.24	0.42	56	113	6100
20478	Bottom Sediment, Oakland	2.25	0.52	59	107	4300
20479	Bottom Sediment, Richmond	1.69	0.46	38	87	3400
20480	Bottom Sediment, San Rafael	1.93	0.53	48	103	9500
20481	Bottom Sediment, (1) Pinole Shoal	1.63	0.36	29	74	1400
20482	Bottom Sediment, (2) Pinole Shoal	1.31	0.05	22	68	7700
20483	Bottom Sediment, Mare Island Strait	2.11	0.64	58	121	2400

Continued on page 2.

Lab No.	Sample Location	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Zinc (Zn)	Oil and Grease
20484	Bottom Sediment, Suisun Bay	1.14	0.10	15	49	5700
20485	Bottom Sediment, Napa	1.76	0.35	31	83	3400
20486	Bottom Sediment, Petaluma	1.63	0.67	49	114	7800

Table 2

Metals Analyses on Tapwater Elutriate[a]
All results in mg/l

Lab No.	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Zinc (Zn)
20475	< 0.001	0.0003	0.009	< 0.01
20476	< 0.001	0.0002	0.003	0.02
20477	< 0.001	0.0002	0.002	0.02
20478	< 0.001	0.0003	0.002	< 0.01
20479	< 0.001	< 0.0001	0.006	< 0.01
20480	< 0.001	0.0002	0.011	< 0.01
20481	< 0.001	0.0033	0.008	0.03
20482	< 0.001	0.0020	0.011	0.05
20483	< 0.001	0.0013	0.021	0.16
20484	< 0.001	0.0010	0.012	0.11
20485	< 0.001	0.0019	0.013	0.25
20486	< 0.001	0.0015	0.007	0.15
20489[b]	0.001	< 0.0001	0.001	0.01

[a]Filtration was through Whatman GF-C paper.

[b]Tapwater used for elutriation.

Continued on Page 3.

Mr. Ray B. Krone
January 24, 1974
Page 3

Table 3

Other Analyses on Tapwater Elutriate[a]
All results in mg/l

Lab No.	IDOD[b]	BOD_5	Suspended Solids[c]	Total Phosphorus (P)	Kjeldahl Nitrogen (N)	Nitrate Nitrogen (N)
20475	1.2	61	223	0.23	2.3	2.1
20476	10	45	57	0.20	7.0	0.45
20477	18	84	143	0.27	8.5	1.2
20478	16	53	403	0.33	5.1	1.4
20479	2.7	48	319	0.32	4.0	0.98
20480	16	36	479	0.22	8.0	1.0
20481	9.3	46	485	0.14	5.7	0.96
20482	7.1	31	1210	0.60	4.6	2.1
20483	18	41	4390	0.70	10.7	1.5
20484	2.4	39	3300	0.69	5.2	0.94
20485	17	97	17700	0.29	6.9	2.5
20486	16	53	789	0.31	6.3	2.1
20489[d]	0	--	1.0	0.009	0.45	0.09

[a]Filtration was through Whatman GF-C paper.

[b]15-minute IDOD was performed on elutriate before settling.

[c]Performed on elutriate settled one hour, but before filtration.

[d]Tapwater used for elutriation.

Continued on Page 4.

AD-A038 313 CORPS OF ENGINEERS SAN FRANCISCO CALIF SAN FRANCISCO--ETC F/G 13/2
DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY. APPENDIX --ETC(U)
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Table 4

Metals Analyses on Seawater Elutriate[a]
All results in mg/l

Lab No.	Cadmium (Cd)	Mercury (Hg)	Lead (Pb)	Zinc (Zn)
20475	0.001	0.0004	0.022	0.03
20476	0.001	0.0011	0.010	< 0.01
20477	< 0.001	0.0133	0.012	0.02
20478	< 0.001	0.0009	0.012	0.06
20479	< 0.001	0.0006	0.024	0.01
20480	< 0.001	0.0006	0.012	0.02
20481	0.001	0.0009	0.008	0.03
20482	< 0.001	0.0003	0.009	0.01
20483	< 0.001	0.0045	0.003	17
20484	< 0.001	0.0008	0.002	0.05
20485	< 0.001	0.0010	0.009	0.05
20486	< 0.001	0.0019	0.012	8.0
20488[b]	0.001	0.0003	0.002	< 0.01

[a]Filtration was through Whatman GF-C paper.

[b]Seawater for elutriation. Supplied by International Engineering Company, taken at Southampton Shoal December 12th 1973.

Continued on Page 5.

Table 5

Other Analyses on Seawater Elutriate[a]
All results in mg/l

Lab No.	IDOD[b]	BOD_5	Suspended Solids[c]	Total Phosphorus (P)	Kjeldahl Nitrogen (N)	Nitrate Nitrogen (N)
20475	2.9	34	28	0.153	1.7	0.80
20476	6.5	115	16	0.217	9.0	0.87
20477	11	150	74	0.216	6.2	0.95
20478	3.0	127	30	0.245	1.7	0.77
20479	1.1	113	88	0.210	4.5	0.95
20480	2.0	107	80	0.097	12	0.82
20481	3.7	111	36	0.043	3.9	0.92
20482	3.0	61	38	0.202	4.5	0.83
20483	9.2	104	308	0.034	15	3.4
20484	3.7	71	56	< 0.001	7.2	0.96
20485	15	164	74	0.034	5.1	5.7
20486	13	175	420	< 0.001	8.4	2.8
20488[d]	0	000	---	0.013	1.1	1.8

[a]Filtration was through Whatman GF-C paper.

[b]15-minute IDOD was performed on elutriate before settling.

[c]Performed on elutriate settled one hour, but before filtration.

[d]Seawater for elutriation. Supplied by International Engineering Company, taken at Southampton Shoal December 12th 1973.

Continued on Page 6.

The organohalogen determinations are still in progress and will be reported separately as soon as results are available.

Perusal of the data reported here reveals some unexpected occurrences. The most suprising discovery was that, following the shaking step, the re-suspended sediments settled much more poorly in the tapwater than in the seawater. This is reflected in the suspended solids results. All of the grease results are somewhat above levels we have previously found to be "normal" for bay sediments. The major difference readily apparent between the two elutriates is in the 5-day BOD results, which are generally 2 to 3 times higher in the seawater elutriate than in the tapwater elutriate.

We wish to mention here that this project has revealed some of the problems associated with the elutriation tests. Among these are the problems mentioned already; additionally, as the method does not specify the exact filtration medium, we chose glass fiber paper, but an absolutely clear elutriate was not always obtained thereby. Some of the filtrations took a very long time, despite centrifuging prior to filtration.

I will send along the organohalogen results as soon as the work is complete.

We hold what remains of the samples, although there is not a great deal left-about two quarts were submitted, rather than the gallon you originally suggested.

Respectfully submitted,

ENVIRONMENTAL QUALITY ANALYSTS, INC.

James B. Tyler

cc: Mr. Ray Samuelson, International Engineering Company

mvs

ENVIRONMENTAL QUALITY ANALYSTS INC.

A DIVISION OF BROWN AND CALDWELL
SAN FRANCISCO ALHAMBRA

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T. V. LUTGE, P.E. 9219C Vice-President
M. L. WHITT, P.E. 15118C General Manager
M. N. LIPSCHUETZ Technical Director
R. D. SMITH Senior Oceanographer
J. B. TYLER Laboratories
C. P. WALTON, Ph.D. Water Chemist

February 12, 1974

Mr. Ray B. Krone
645 Coolidge Street
Davis, California

ORGANOHALOGEN DETERMINATIONS ON ELUTRIATES

We have completed the organohalogen determination on tap and sea water elutriates as requested by you on the twelve bay sediment samples submitted by International Engineering Company.

The elutriates were extracted by repeated partitioning into 15 percent ethyl ether in hexane. The extracts were cleaned up on a 2 cm x 10 cm florisil column. Chlorinated hydrocarbons were detected by GLC using the electron capture detector.

The analysis would have detected Arochlors 1221-1262 in addition to most non-ionic chlorinated pesticides. The low detection limits were achieved by analyzing one liter elutriates.

Table 1: Tapwater Elutriates

Results — Parts per Billion — nd= none detected

Sample Number	Non-Ionic Chlorinated Hydrocarbons: Polychlorobiphenyls PCB 1242	PCB 1254	Pesticidal
Background*	nd	nd	nd
20475	nd	nd	nd
20476	nd	nd	nd
20477	nd	nd	nd
20478	nd	nd	nd
20479	nd	nd	nd
20480	nd	nd	nd
20481	nd	nd	nd
20482	nd	nd	nd

WATER QUALITY INVESTIGATIONS AND MARINE STUDIES / BIOLOGICAL AND CHEMICAL LABORATORIES

ENVIRONMENTAL QUALITY ANALYSTS INC. 66 MINT STREET SAN FRANCISCO CA 94103 (415)982-2442

Results — Parts per Billion — nd= none detected

Sample Number	Non-Ionic Chlorinated Hydrocarbons: Polychlorobiphenyls PCB 1242	PCB 1254	Pesticidal
20483	nd	0.1	nd
20484	nd	nd	nd
20485	nd	nd	nd
20486	nd	nd	nd
Detection Limits	0.1	0.1	0.05-0.1

*San Francisco Water Department (tapwater).

Table 2: Seawater Elutriates

Results — Parts per Billion — nd= none detected

Sample Number	Non-Ionic Chlorinated Hydrocarbons: Polychlorobiphenyls PCB 1242	PCB 1254	Pesticidal: Chlordane	DDE	DDT	Others
Background*	nd	nd	nd	nd	nd	nd
20475	nd	nd	nd	0.05	nd	nd
20476	nd	nd	nd	nd	nd	nd
20477	0.10	0.10	nd	nd	nd	nd
20478	nd	nd	nd	nd	nd	nd
20479	nd	0.10	nd	nd	nd	nd
20480	0.10	0.10	nd	nd	nd	nd
20481	0.15	0.15	nd	nd	nd	nd
20482	0.20	0.20	nd	nd	nd	nd
20483	0.30	0.25	nd	nd	nd	nd
20484	0.25	0.17	nd	nd	nd	nd
20485	0.40	0.20	nd	nd	0.10	nd
20486	0.16	0.17	nd	0.05	nd	nd
Detection Limits	0.10	0.10	0.10	0.05	0.05	0.05

*Water for elutriation supplied by International Engineering Company taken at Southampton Shoal, December 12th, 1973.

In connection with our earlier report on other elutriate tests, I wish to emphasize that the "Immediate Oxygen Demand" (IDOD) and 5-day Biochemical Oxygen Demand (BOD_5) determinations were made **on** the elutriates, in accordance with our interpretation of EPA Region IX's DSDC. Since that work was done, I have spoken with Dr. Ho Young at EPA's Alameda laboratory. Dr. Young expects to disseminate around 1 May a tentative set of methods of analysis for the elutriation approach. It is clear that EPA really desires IDOD and BOD_5 on the sediment (and other tests on the elutriate). The proposed methods will incorporate this change of emphasis, pending (I presume) Cincinnati's approval.

As of this writing, the exchangable bases work is in progress, slowed slightly by some hospitalized personnel. I will communicate our findings at the earliest time possible.

Respectfully submitted,

ENVIRONMENTAL QUALITY ANALYSTS, INC.

James B. Tyler

cc: Mr. Ray Samuelson, International Engineering Company

mvs

ENVIRONMENTAL QUALITY ANALYSTS INC. 66 MINT STREET SAN FRANCISCO CA 94103 (415)982-2442

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M. N. LIPSCHUETZ Technical Director
R. D. SMITH Senior Oceanographer
J. B. TYLER Laboratories
C. P. WALTON, Ph.D. Water Chemist

February 20, 1974

Mr. Ray B. Krone
645 Coolidge Street
Davis, California

EXCHANGEABLE BASES, SEDIMENT SAMPLES

We have completed determination of exchangeable metals on four sediment samples as requested by Ray Samuelson on January 28th. The results are shown below, and are given in terms of ppm of metal on an air-dried weight basis.

Lab No.:	20475	20476	20478	20483
Identification:	San Francisco	(1) Redwood City	Oakland	Mare Island Strait
odium (Na)	9,300	18,200	14,000	7,150
Potassium (K)	2,200	1,750	1,750	2,000
Calcium (Ca)	5,000	9,000	5,000	3,500
Magnesium (Mg)	190	195	195	195
Cadmium (Cd)	0.3	0.7	0.4	0.4
Zinc (Zn)	23	56	31	33
Lead (Pb)	6.0	2.0	8.0	7.0

All determinations were made by atomic absorbtion spectrophotometry.

For this work we used the method of H.D. Chapman which you sent, through the 800 C ignition step. The residue resulting was taken up in 10 ml of concentrated hydrochloric acid; this was transferred to a 100 ml volumetric flask and diluted to the mark with distilled water. Further dilutions of this were analyzed by atomic

Continued on page 2.

absorbtion techniques. Mercury was not run, as it would have been volatilized during the ignition step.

Respectfully submitted,

ENVIRONMENTAL QUALITY ANALYSTS, INC.

James B. Tyler

cc: Mr. Ray Samuelson
International Engineering Company

mvs

APPENDIX C

PHYSICAL TESTING OF SEDIMENTS

APPENDIX C

PHYSICAL TESTING OF SEDIMENTS

The samples taken by CSO Laboratory were delivered to the Harding-Lawson Associates laboratory in plastic tubes in a relatively undisturbed state; the remainder of the samples were disturbed.

The testing program included Atterberg Limits tests and a hydrometer analysis on a sample from each location. As-received moisture contents were performed on some of the samples and dry density determinations were made where possible. On four samples (Nos. 1, 2, 8 and 9) the maximum dry density and optimum moisture contents were determined in accordance with the ASTM D1557-70 (C) test method. In addition, samples of these four materials were compacted in a mold to 85 and 90 percent relative compaction and unconfined compression and consolidation tests were performed.

The results of the Atterberg Limits, moisture content / dry density and unconfined compression tests are summarized on Exhibit C-1 and the hydrometer tests (dispersed analyses) on Exhibits C-2 through C-4. The moisture/density relationships are shown on Exhibits C-5 and C-6 and the consolidation test data on Exhibits C-7 through C-10. Moisture/volume relationships are shown on Exhibit C-11.

Six of the 10 samples had 80 percent or more passing the No. 200 sieve; 9 out of the 10 had at least 50 percent or more passing the No. 200 sieve. Thus, except for the Suisun Bay sample, all are classified as clays. Sand contents varied from 52 percent to 1 percent.

The four samples selected for strength and consolidation testing are fairly representative of these various soil types.

As indicated by the data on Exhibit C-1, the soil has moderate shear strengths when compacted to 85 percent relative compaction and moderate to high shear strengths when compacted to 90 percent relative compaction and tested in an unconfined compression test. Consolidation tests revealed that the clay soils

are of low compressibility up to loads of as much as 3000 psf. These soils tend to swell upon inundation even under moderate loads.

Most of these soils are classified as clays of high plasticity. These soils typically show moderate to large swelling and shrinking upon changes in moisture content. When used as compacted fill, they should be treated as expansive clays.

Consolidation testing of unprocessed slurry was not performed because normal consolidation testing of liquid or semi-liquid slurry would not be valid in normal consolidation apparatus. Reference 83 cites instances in which consolidation tests have been performed on liquid slurry using specially designed equipment. Several empirical equations were developed to relate consolidation characteristics of various dredgings to their void ratio and consolidation pressure.

EXHIBIT C - I

LOCATION	NO.	L.L.	P.L.	P.I.	CLASSIFIED	% PASSING #200 SIEVE	AS RECEIVED MOISTURE (%)	AS RECEIVED DRY DENSITY (PCF)	COMPACTION TESTS OPT. MOISTURE (%)	COMPACTION TESTS MAXIMUM DRY DENSITY (PCF)	REMOLDED TESTS UNCONFINED COMPRESSION	REMOLDED TESTS CONSOLIDATION
San Francisco	1	59	24	35	CH	69			20.5	105	92 pcf @ 27.2% τ = 5000 psf	88 pcf @ 27.4% 94 pcf @ 26.7%
Redwood City	2	79	32	47	CH	81			24.0	94	80 pcf @ 37.3% τ = 3000 psf	79 pcf @ 40.1%
Oakland	3	78	31	47	CH	99	111.6					
	4	No Samples Received										
Richmond	5	57	24	33	CH	86	82.7	51				
	6	No Samples Received										
San Rafael	7	72	27	45	CH	96	115.1					
Pinole Shoal	8	48	22	26	CL	55			15.0	117	99 pcf @ 22.3% τ = 970 psf	100 pcf @ 23.4%
Mare Island	9	84	34	50	CH	99	112.4	41	29.5	95	85 pcf @ 35.8% τ = 1700 psf	80 pcf @ 35.7%
Suisun Bay	10	43	23	20	SC	48	66.2	64				
Napa River	11	44	25	19	CL	64	69.9					
Petaluma River	12	86	31	55	CH	99	124.9					

*Compaction Method is ASTM D1557-70(C) max in pounds/cubic foot

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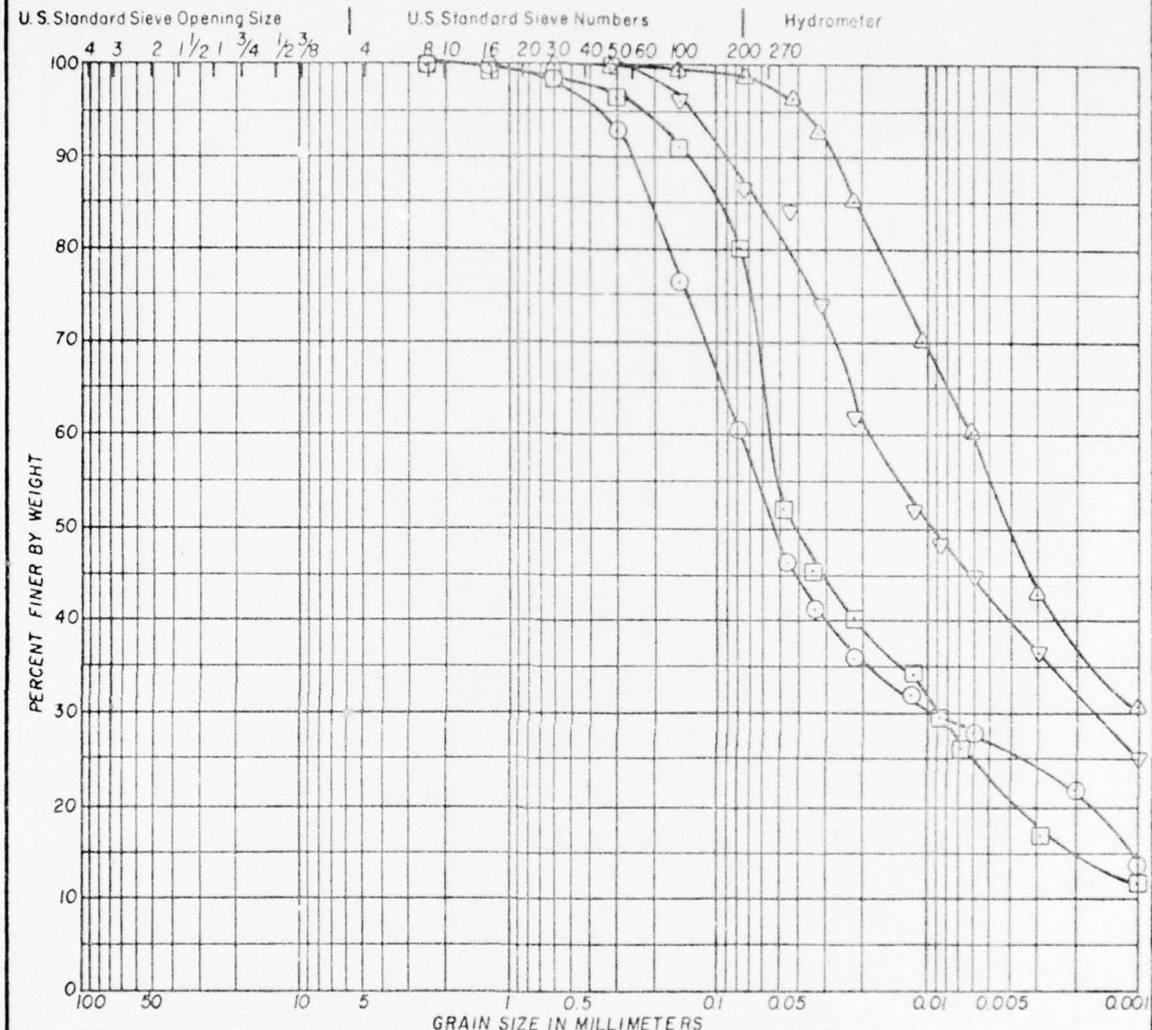
LABORATORY DATA
Dredge Disposal Study
San Francisco Bay and Estuary

PLATE

EXHIBIT C - 2

RF24



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
⊙	Hole #1 (San Francisco)	DARK GRAY SANDY CLAY (CH)
⊡	Hole #2 (Redwood City)	DARK GRAY SANDY CLAY (CH)
△	Hole #3 (Oakland)	GRAY SANDY CLAY (CH)
▽	Hole #5A (Richmond)	DARK GRAY FINE SANDY CLAY (CH)

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PARTICLE SIZE ANALYSIS

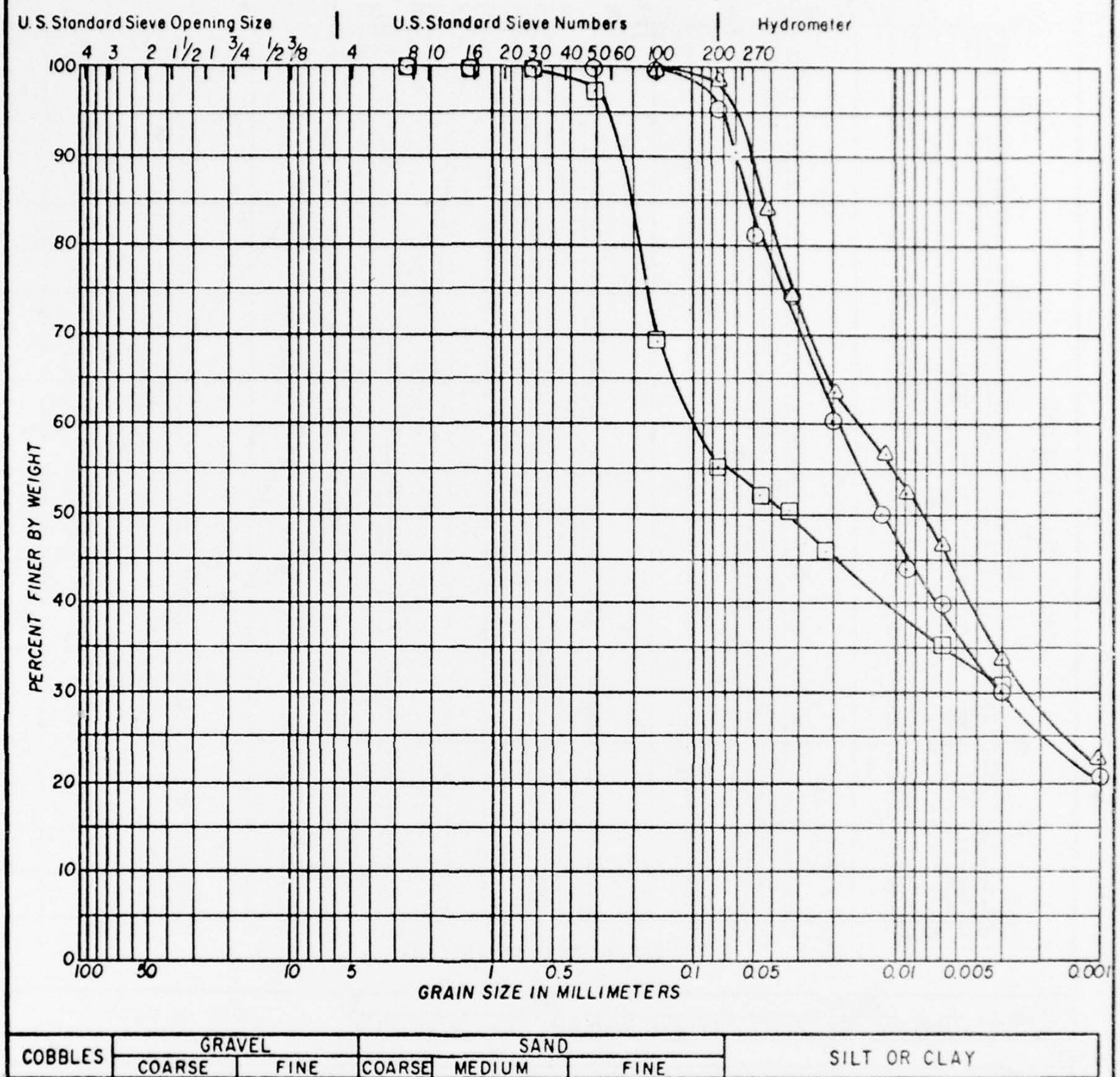
Dredge Disposal Study

San Francisco Bay and Estuary

PLATE

EXHIBIT C-3

RF24



Symbol	Sample Source	Classification
⊙	Hole #7 (San Rafael Creek)	DARK GRAY FINE SANDY CLAY (CH)
⊡	Hole #8 (Pinole Shoal)	DARK GRAY SANDY CLAY (CL)
△	Hole #9 (Mare Island)	DARK GRAY SANDY CLAY (CH)

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PARTICLE SIZE ANALYSIS

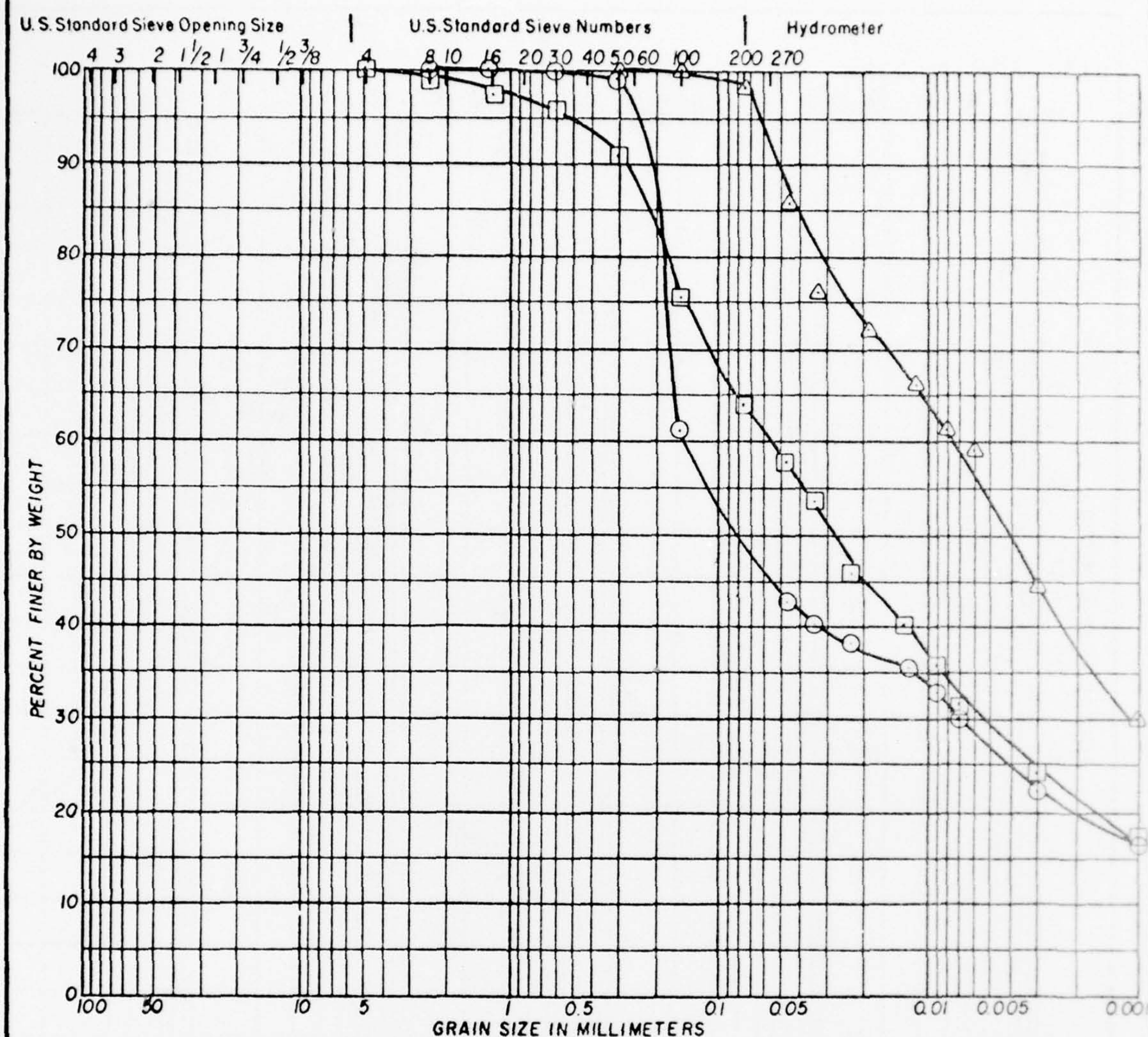
Dredge Disposal Study

San Francisco Bay and Estuary

PLATE

EXHIBIT C - 4

RF24



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
⊙	Hole #10 (Suisun Bay)	DARK GRAY CLAYEY SAND (SC)
⊡	Hole #11 (Napa River)	DARK GRAY SANDY SILTY CLAY (CL)
△	Hole #12 (Petaluma Creek)	DARK GRAY CLAY (CH)

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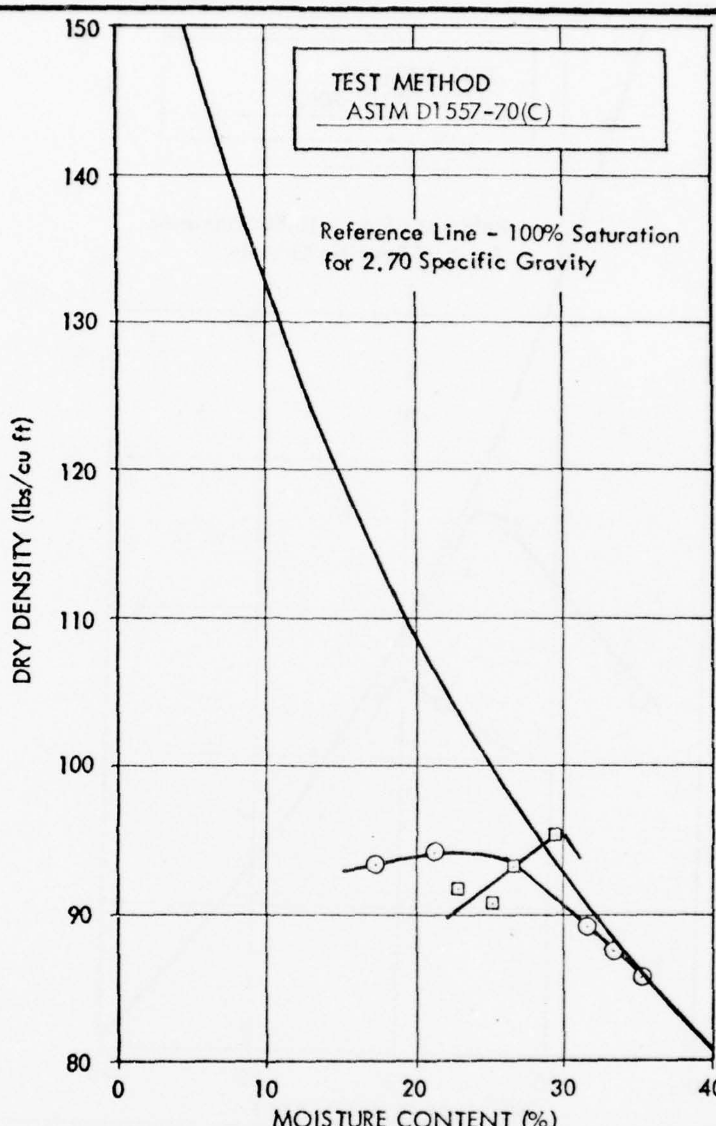
PARTICLE SIZE ANALYSIS

Dredge Disposal Study
San Francisco Bay and Estuary

PLATE



Symbol	Sample Source	Classification	Optimum Moisture (%)	Maximum Dry Density (pcf)
⊙	Station 2 (Redwood City)	GRAY SANDY CLAY (CH)	24.0	94
⊡	Station 9 (Mare Island)	DARK GRAY SANDY CLAY (CH)	29.5	95

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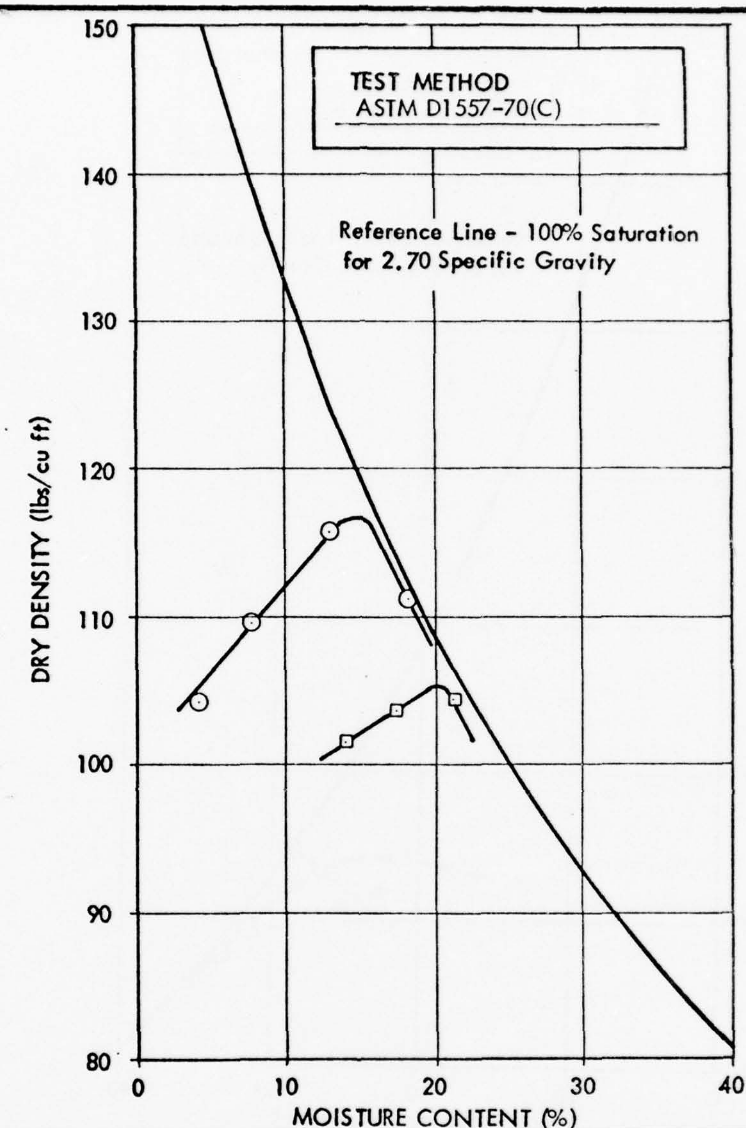
COMPACTION TEST DATA
Dredge Disposal Study
San Francisco Bay and Estuary

PLATE

RF21



Symbol	Sample Source	Classification	Optimum Moisture (%)	Maximum Dry Density (pcf)
⊙	Station 8 (Pinole Shoal)	GRAY SANDY CLAY (CL)	15.0	117
⊡	Station 1 (San Francisco)	DARK GRAY SANDY CLAY (CH)	20.5	105

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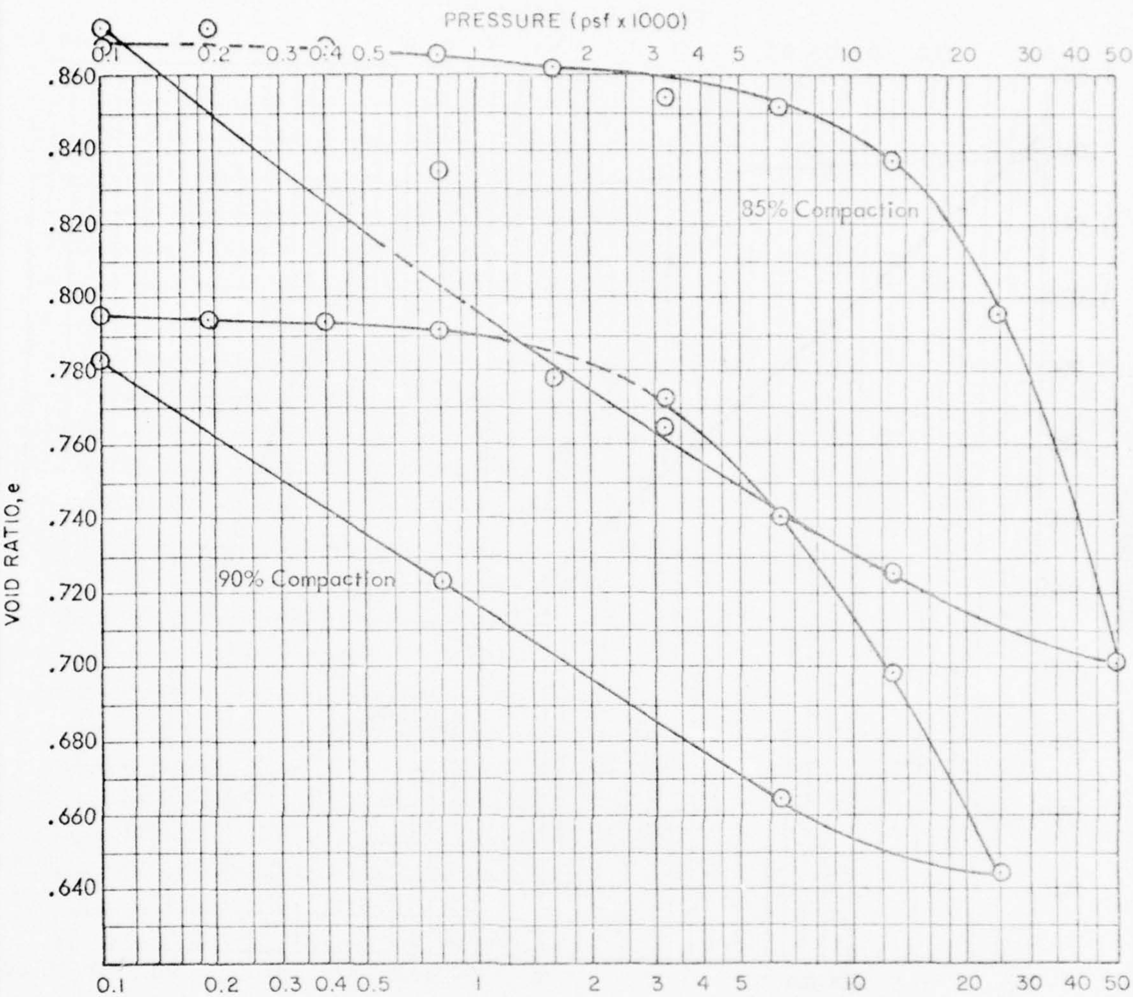
COMPACTION TEST DATA
Dredge Disposal Study
San Francisco Bay and Estuary

PLATE

RF30



TYPE OF SPECIMEN	Remolded			BEFORE TEST				AFTER TEST			
DIAMETER (in.) 2.43	HEIGHT (in.) 0.80			MOISTURE CONTENT	w_o	27.4 26.7	%	w_f	33.0	29.1	%
OVERBURDEN PRESS., P_o	–	psf		VOID RATIO	e_o	.874 .796		e_f	.868	.782	
PRECONSOL. PRESS., P_c	–	psf		SATURATION	S_o	83 91	%	S_f	100	100	%
COMPRESSION INDEX, C_c	0.19			DRY DENSITY	γ_d	88 94	pcf	γ_d	89	95	pcf
LL –		PL –		PI –		G_s 2.70 Assumed					
CLASSIFICATION GRAY-GREEN SANDY CLAY (CL)				SOURCE Station #1							

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CONSOLIDATION TEST REPORT
Dredge Disposal Study
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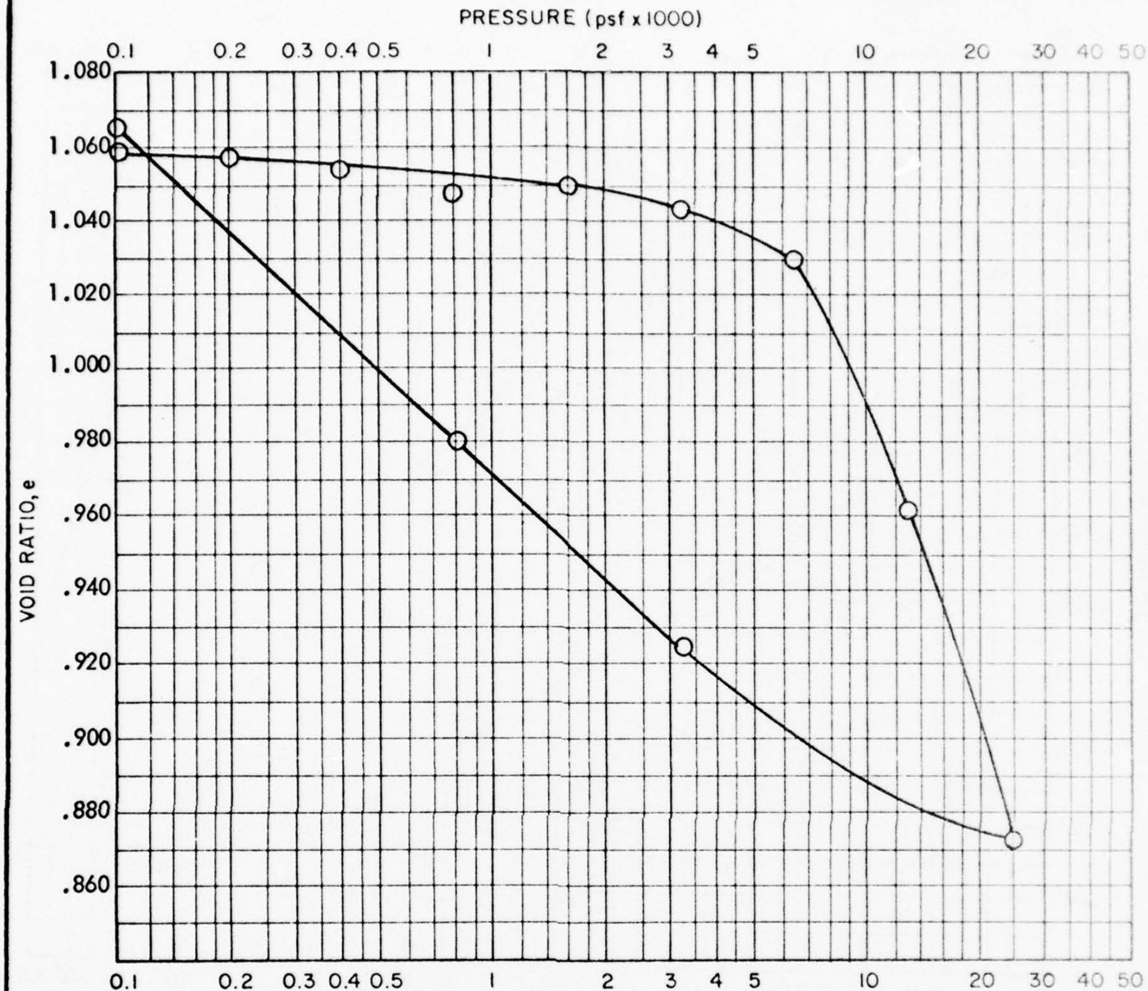
RF30



TYPE OF SPECIMEN Remolded				BEFORE TEST				AFTER TEST	
DIAMETER (in.) 2.43	HEIGHT (in.) 0.80		MOISTURE CONTENT	w_o	40.1	%	w_f	40.8	%
OVERBURDEN PRESS., P_o	-	psf	VOID RATIO	e_o	1.064		e_f	1.067	
PRECONSOL. PRESS., P_c	-	psf	SATURATION	S_o	98	%	S_f	100	%
COMPRESSION INDEX, C_c	-		DRY DENSITY	γ_d	79	pcf	γ_d	79	pcf
LL -	PL -		PI -				G_s 2.60 Assumed		
CLASSIFICATION GRAY-GREEN SANDY CLAY (CL)			SOURCE Station #2						

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CONSOLIDATION TEST REPORT
Dredge Disposal Study
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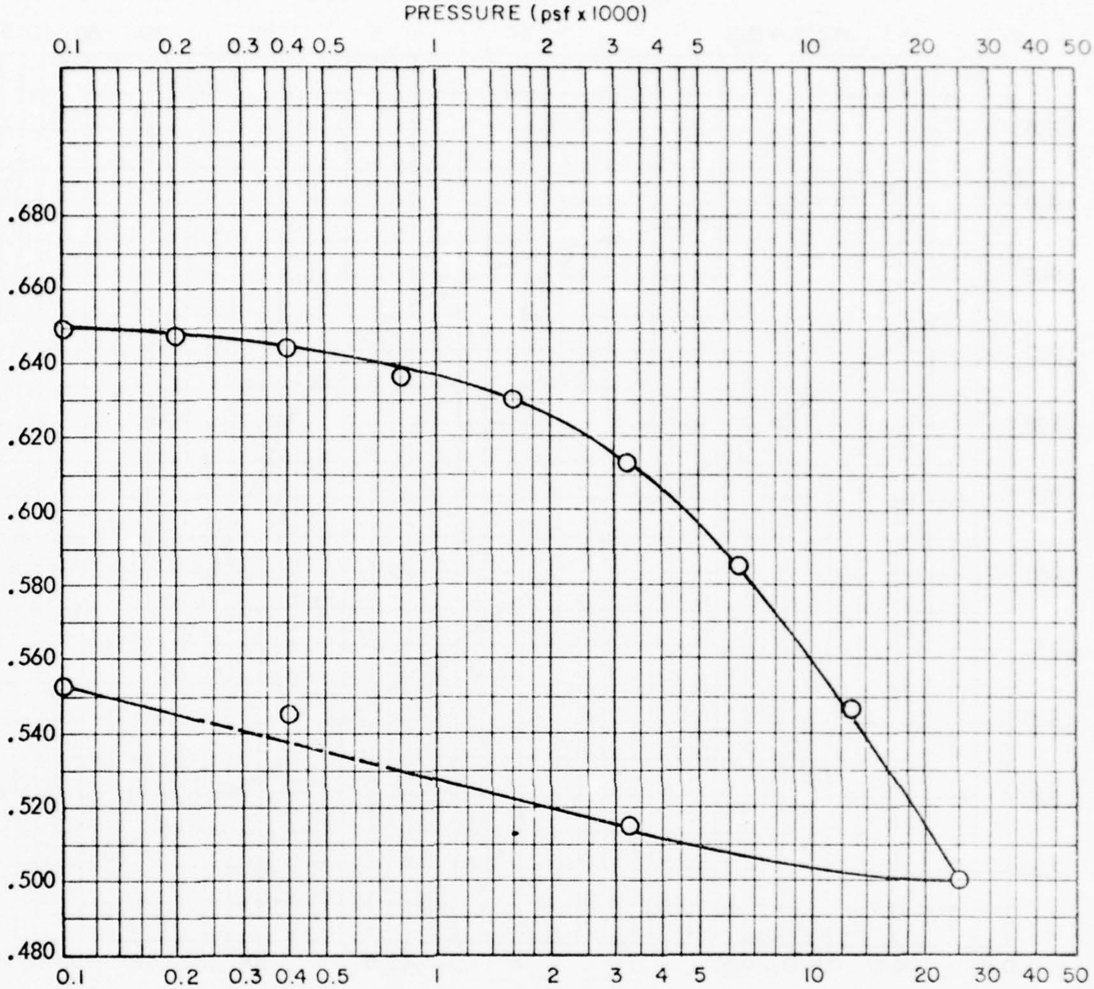


TYPE OF SPECIMEN Remolded		BEFORE TEST			AFTER TEST		
DIAMETER (in.) 2.43	HEIGHT (in.) 0.80	MOISTURE CONTENT	w_o	23.4 %	w_f	20.9 %	
OVERBURDEN PRESS., P_o — psf		VOID RATIO	e_o	.658	e_f	.552	
PRECONSOL. PRESS., P_c — psf		SATURATION	S_o	94 %	S_f	100 %	
COMPRESSION INDEX, C_c 0.16		DRY DENSITY	γ_d	100 pcf	γ_d	107 pcf	
LL —	PL —	PI —		G_s 2.65 Assumed			
CLASSIFICATION GRAY SANDY CLAY (CL)		SOURCE Station #8					

HARDING - LAWSON ASSOCIATES

Consulting Engineers and Geologists

Job No. 5954,002.01 Appr: ______ Date 2/22/74

CONSOLIDATION TEST REPORT

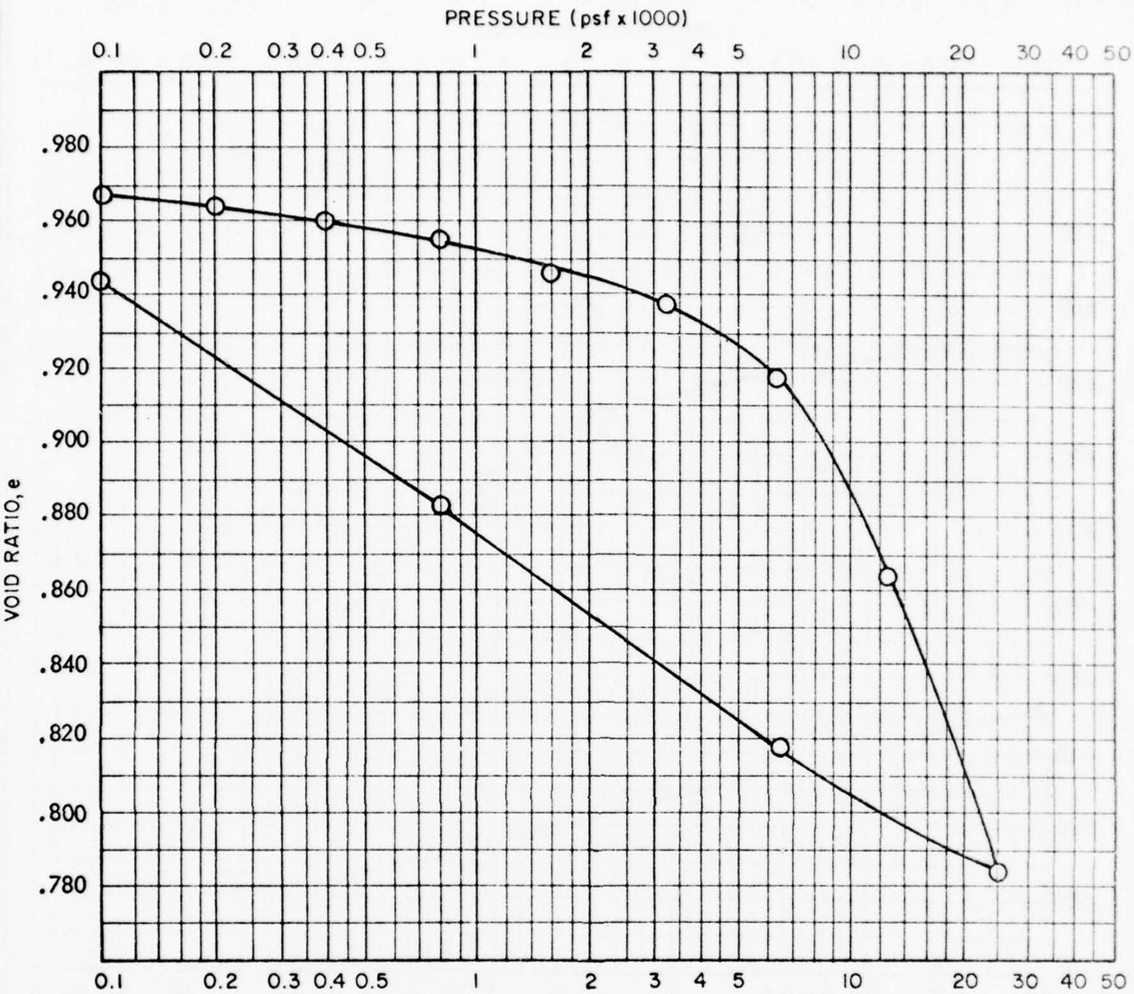
Dredge Disposal Study

San Francisco Bay and Estuary

PLATE

EXHIBIT C-10

RF30



TYPE OF SPECIMEN Remolded		BEFORE TEST			AFTER TEST		
DIAMETER (in.) 2.43	HEIGHT (in.) 0.80	MOISTURE CONTENT	w_o	35.7 %	w_f	36.2 %	
OVERBURDEN PRESS., P_o	- psf	VOID RATIO	e_o	.969	e_f	.944	
PRECONSOL. PRESS., P_c	- psf	SATURATION	S_o	96 %	S_f	100 %	
COMPRESSION INDEX, C_c	.28	DRY DENSITY	γ_d	83 pcf	γ_d	84 pcf	
LL -	PL -	PI -		G_s 2.60 Assumed			
CLASSIFICATION GREEN-GRAY SANDY CLAY (CL)		SOURCE Station #9					

HARDING - LAWSON ASSOCIATES

Consulting Engineers and Geologists

Job No. 5954,002.01 Appr: Date 2/22/74

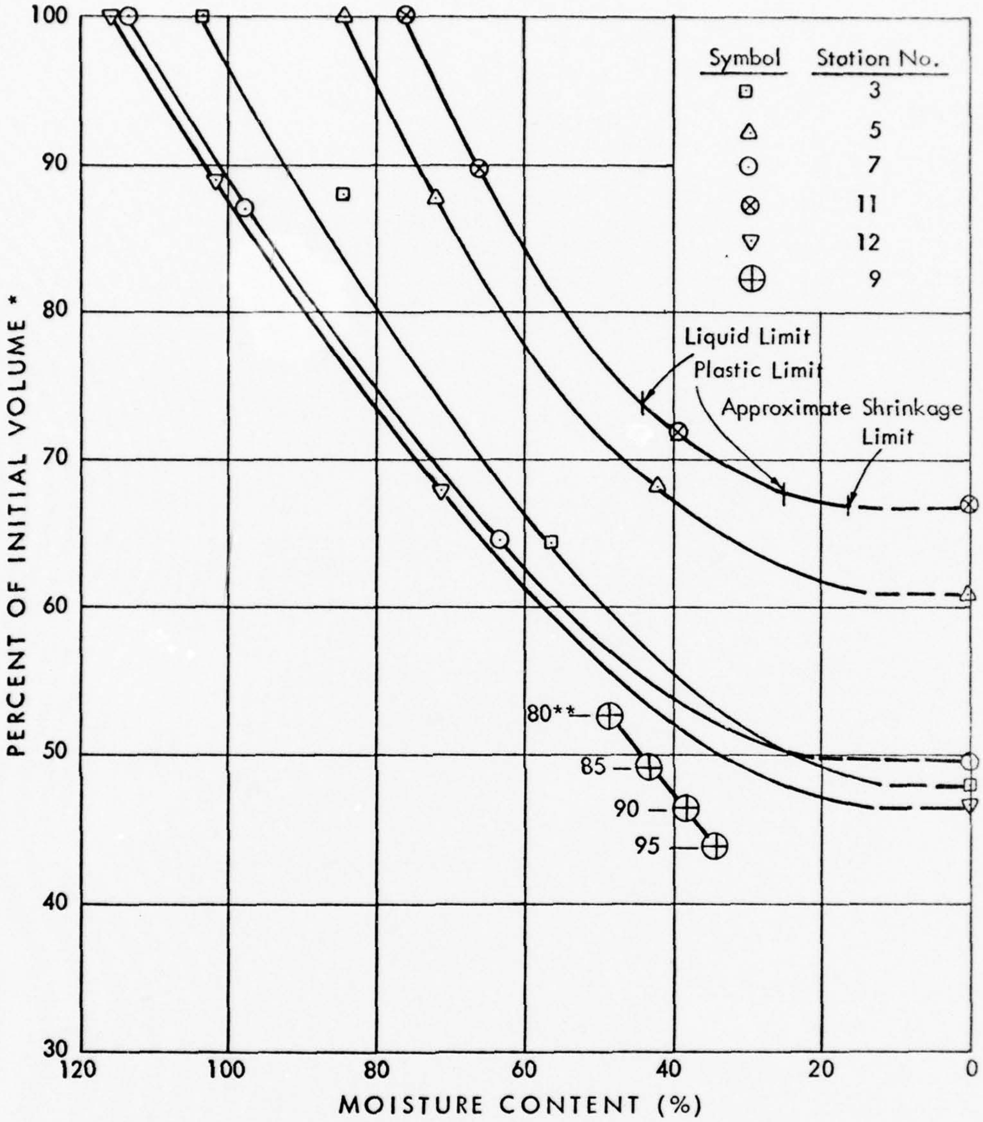
CONSOLIDATION TEST REPORT

Dredge Disposal Study

San Francisco Bay and Estuary

PLATE

RF1



*100% volume is as received moisture content. Since the saturation is 100%, it is assumed that the 100% volume is approximately the Shoal or Bank Run Volume.

** Percent compaction from compaction curve from Station No. 9 - sample from Station 9 is similar to those from Stations 3, 7, 12

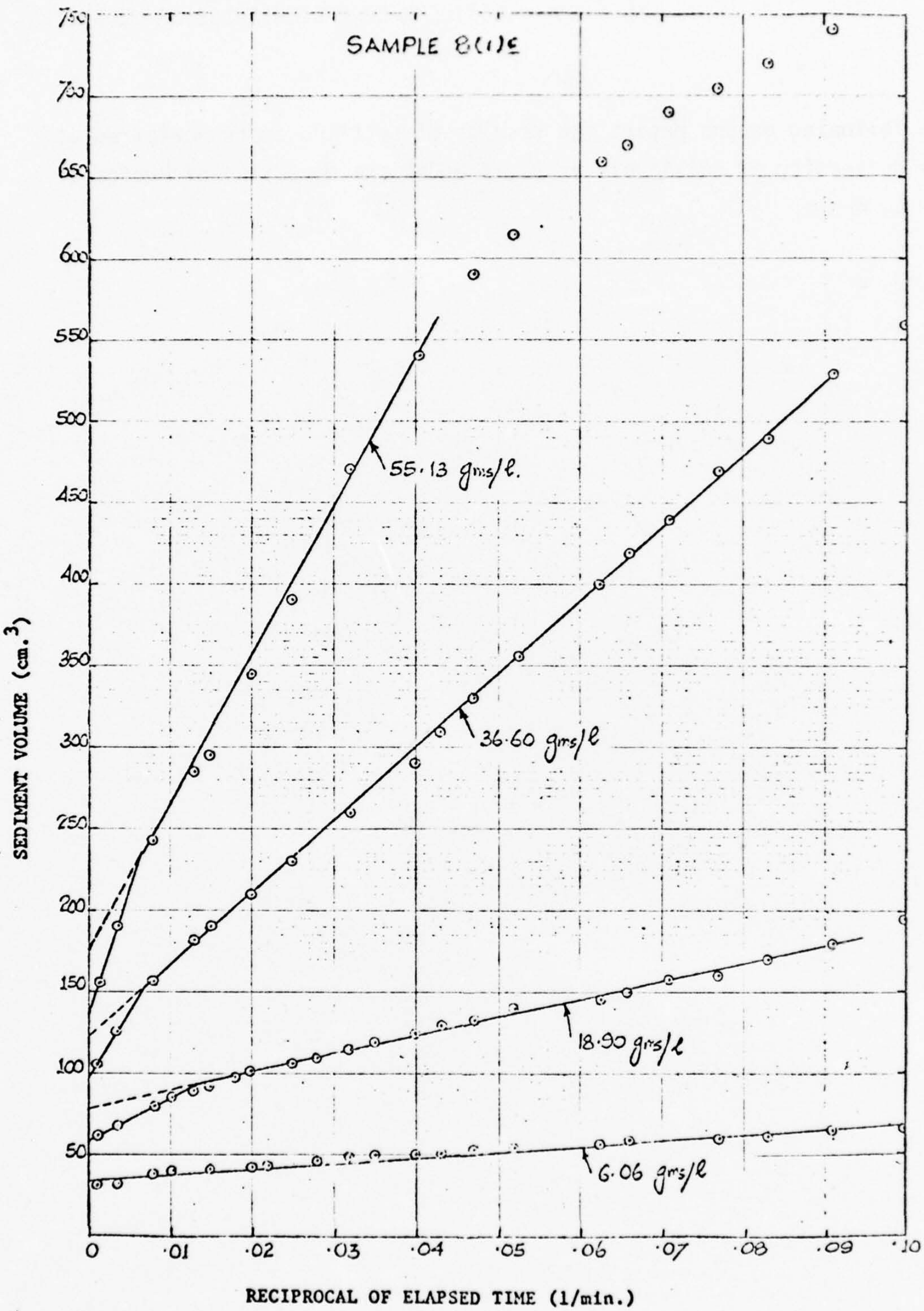
HARDING - LAWSON ASSOCIATES *Consulting Engineers and Geologists*	VOLUME vs. MOISTURE CONTENT Dredge Disposal Study San Francisco Bay and Estuary	PLATE
Job No. 5954,002.01 Appr: ____ Date 2/25/74		

APPENDIX D

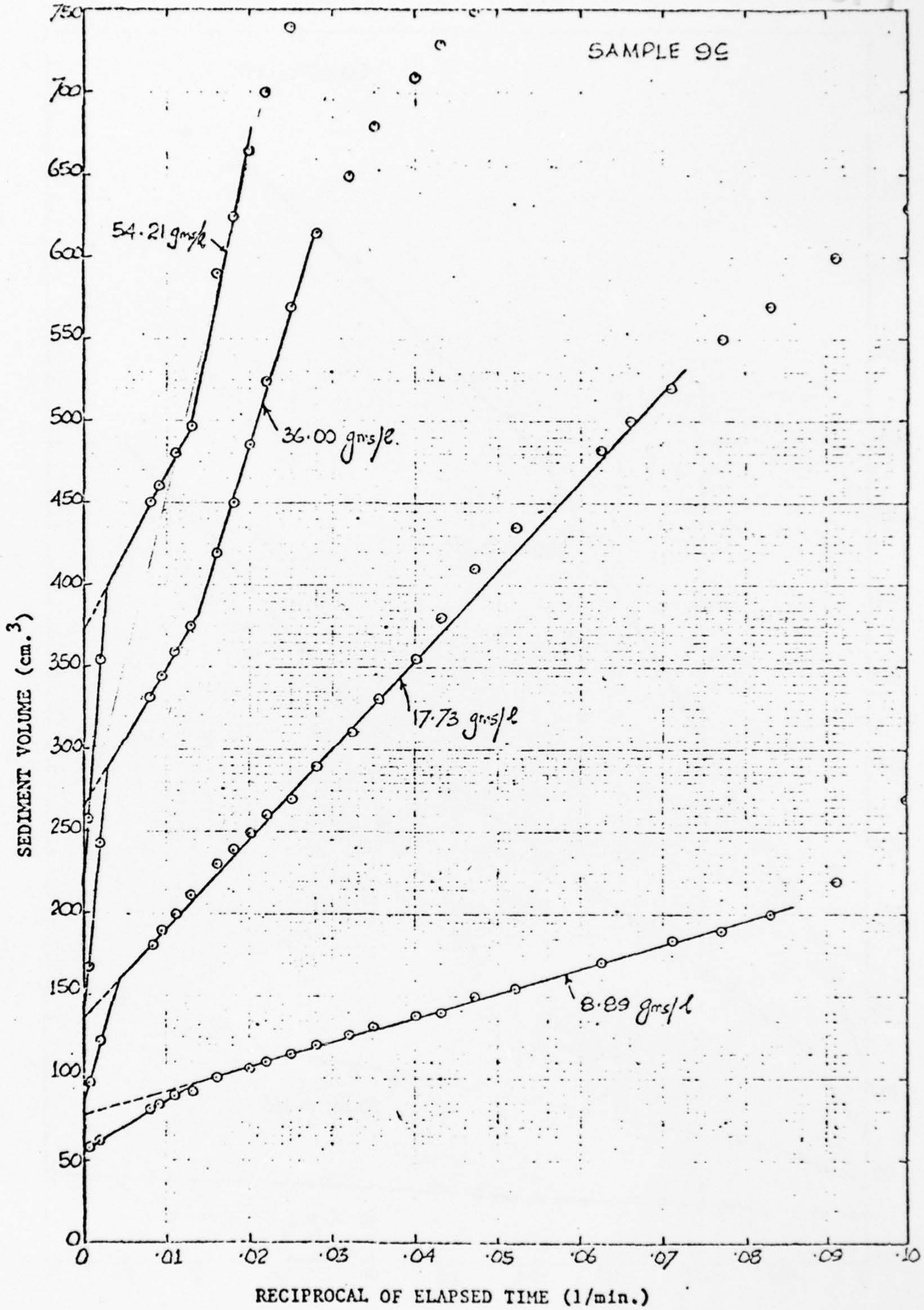
SETTLING CHARACTERISTICS OF SEDIMENTS

APPENDIX D
SETTLING CHARACTERISTICS OF SEDIMENTS

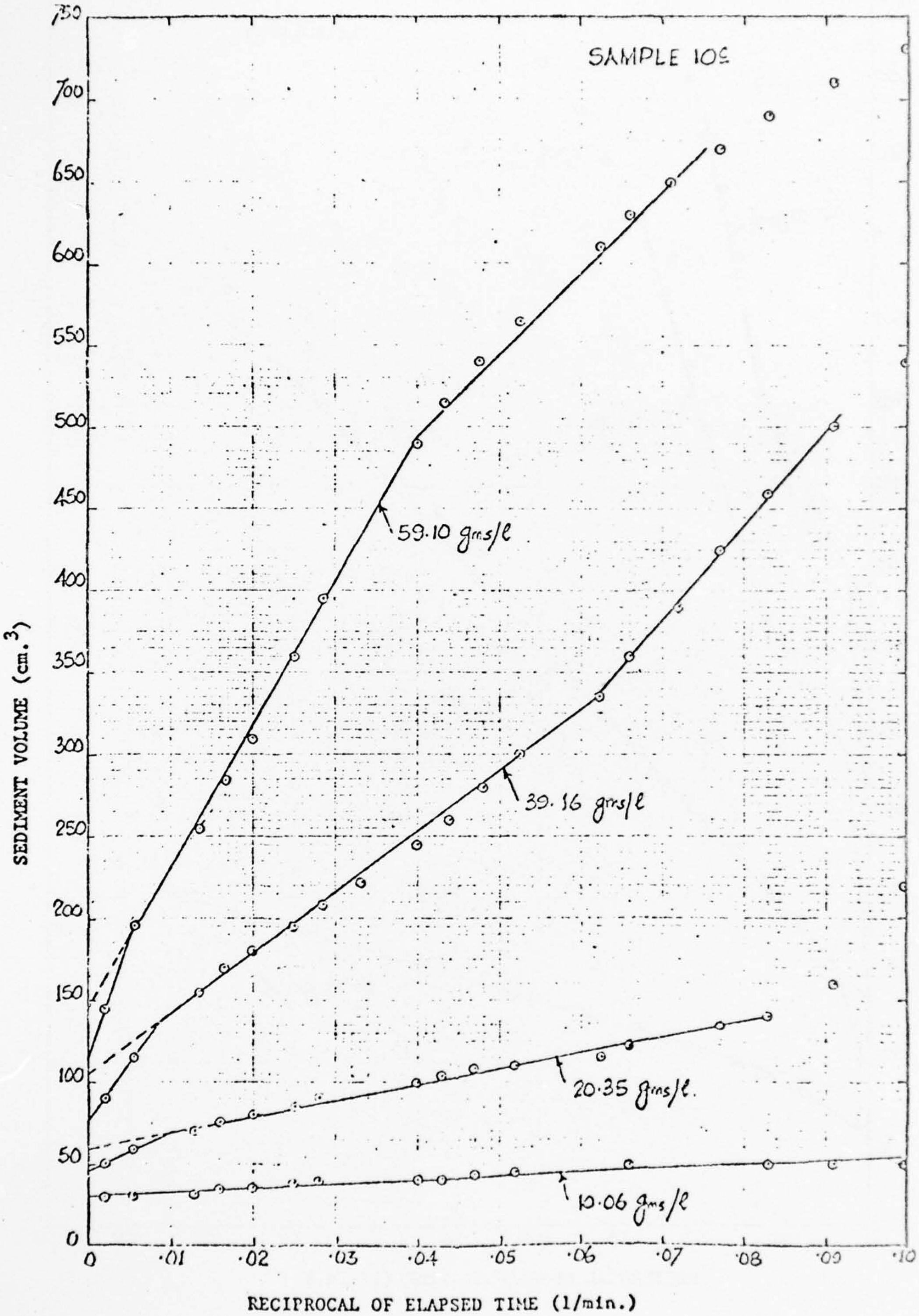
The following graphs depict the results of settling tests performed at the University of California at Davis under the direction of Professor Ray B. Krone.



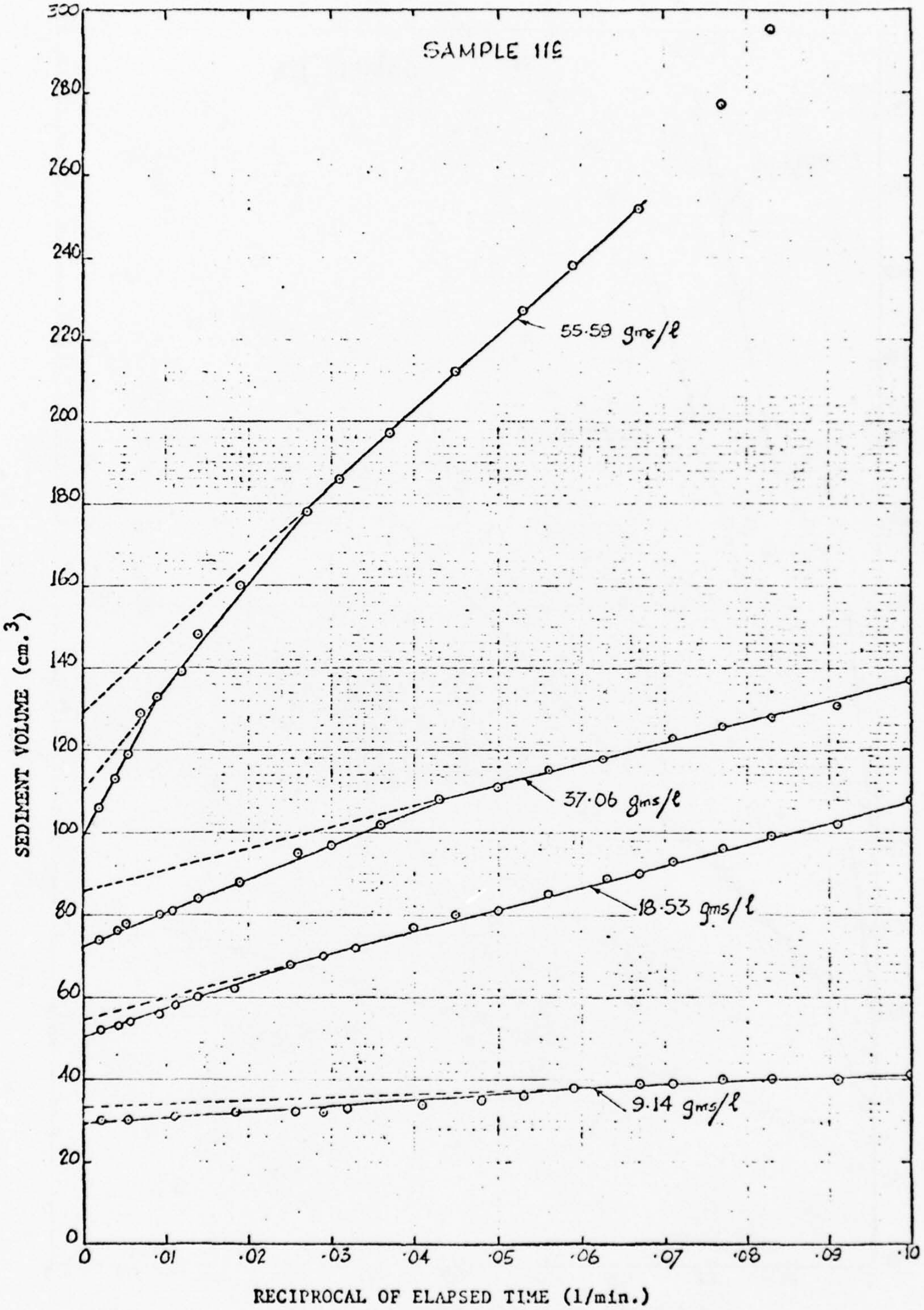
Hindered Settling Test.



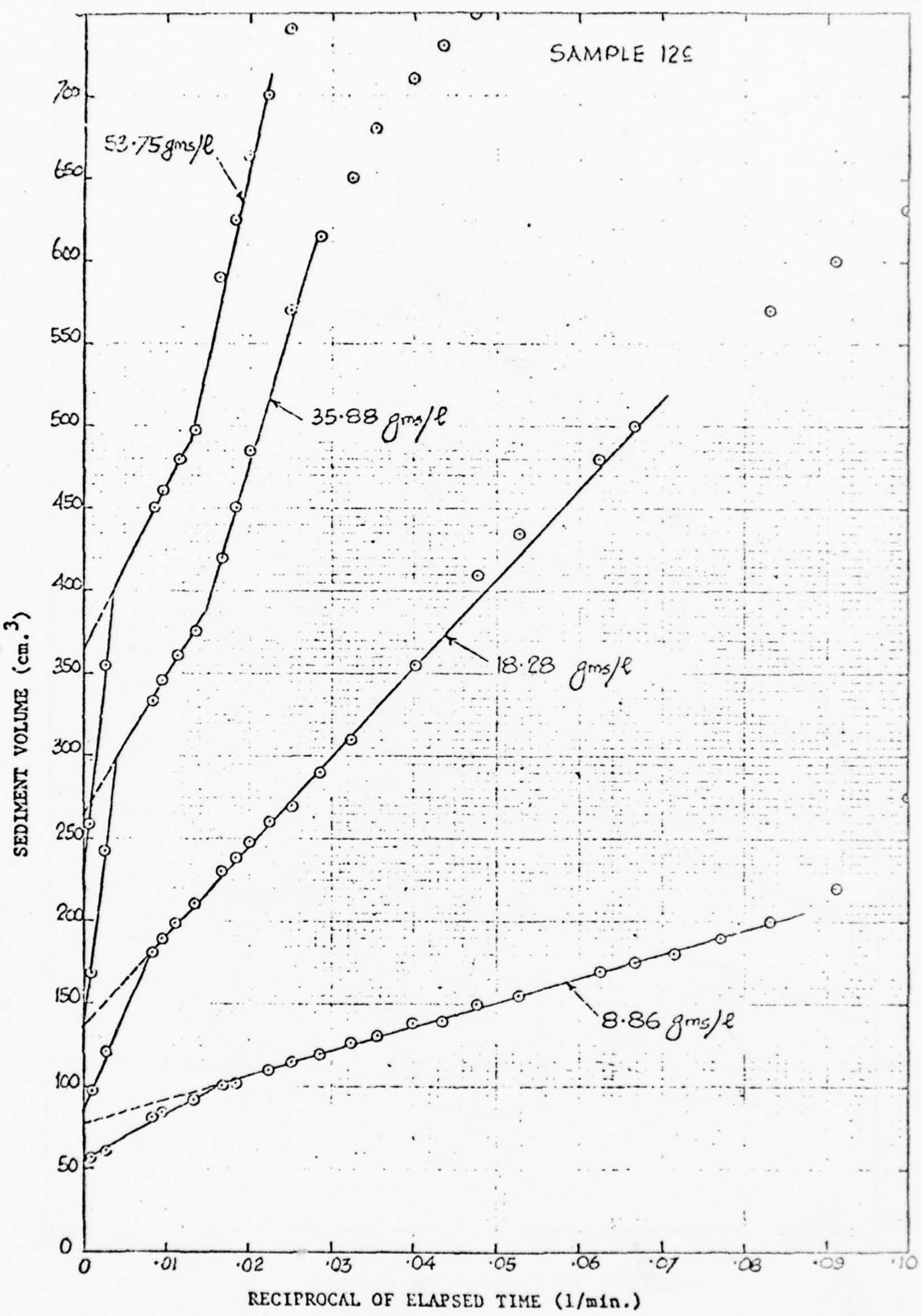
Hindered Settling Test.



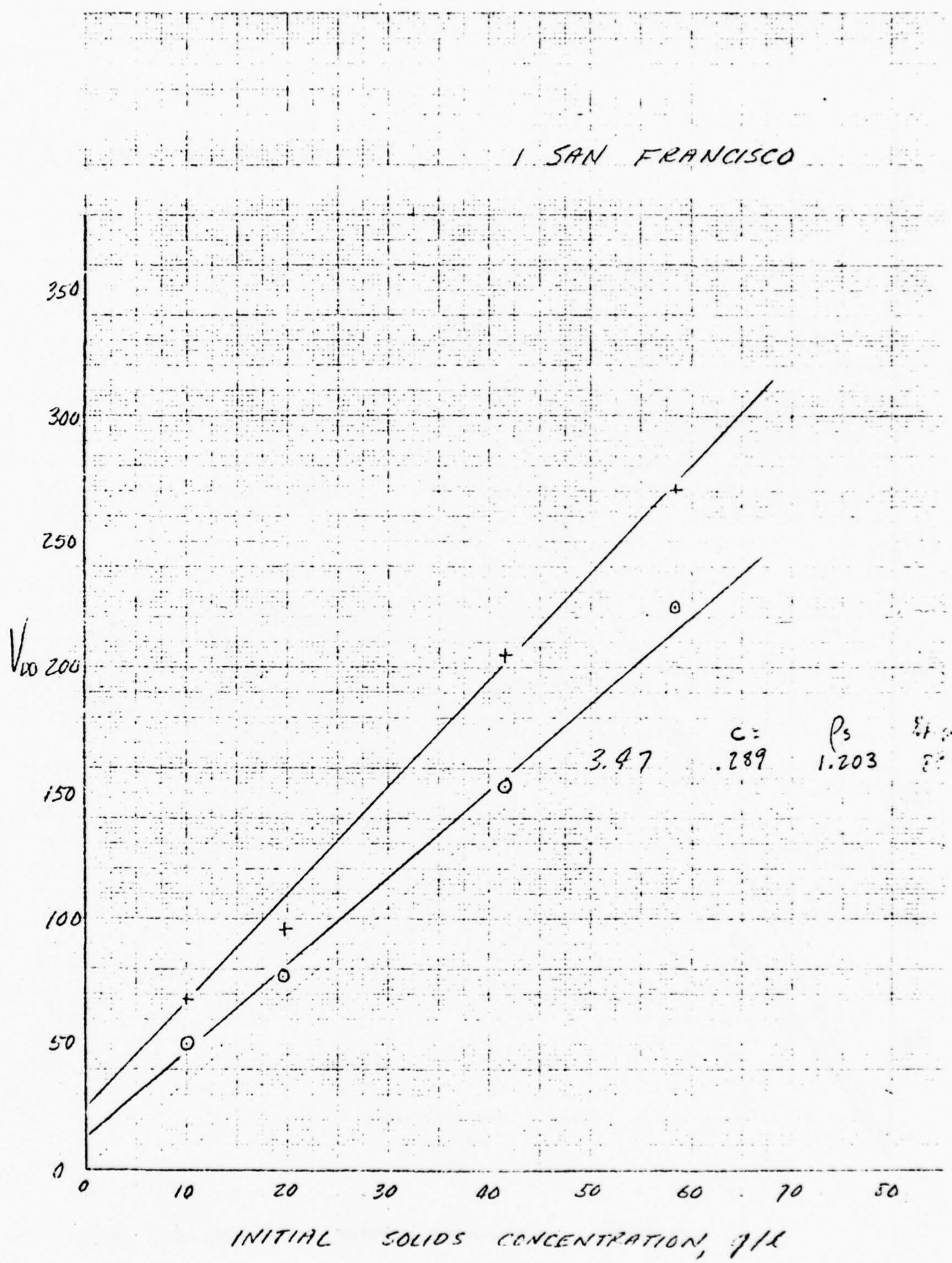
Hindered Settling Test.



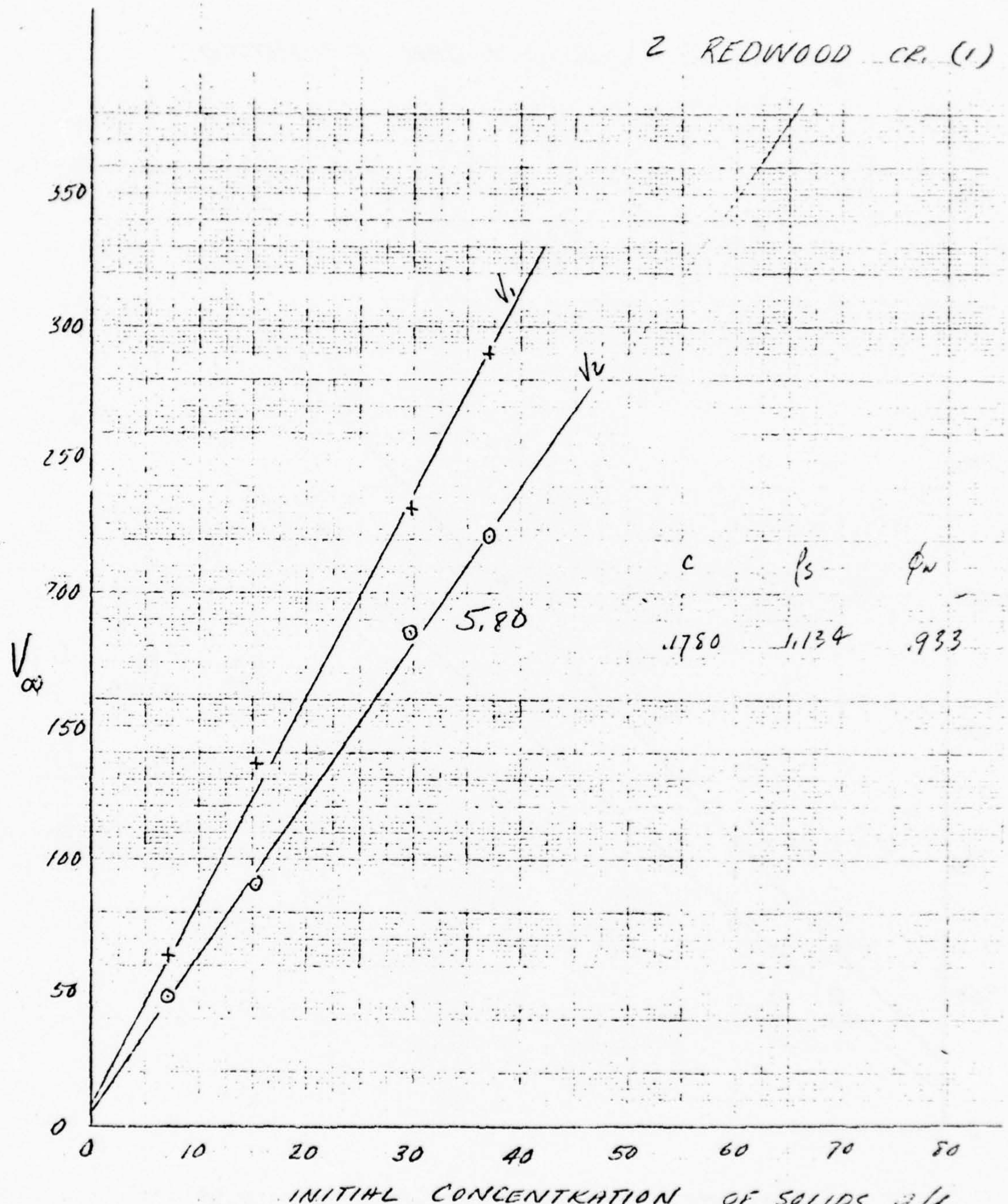
Hindered Settling Test.



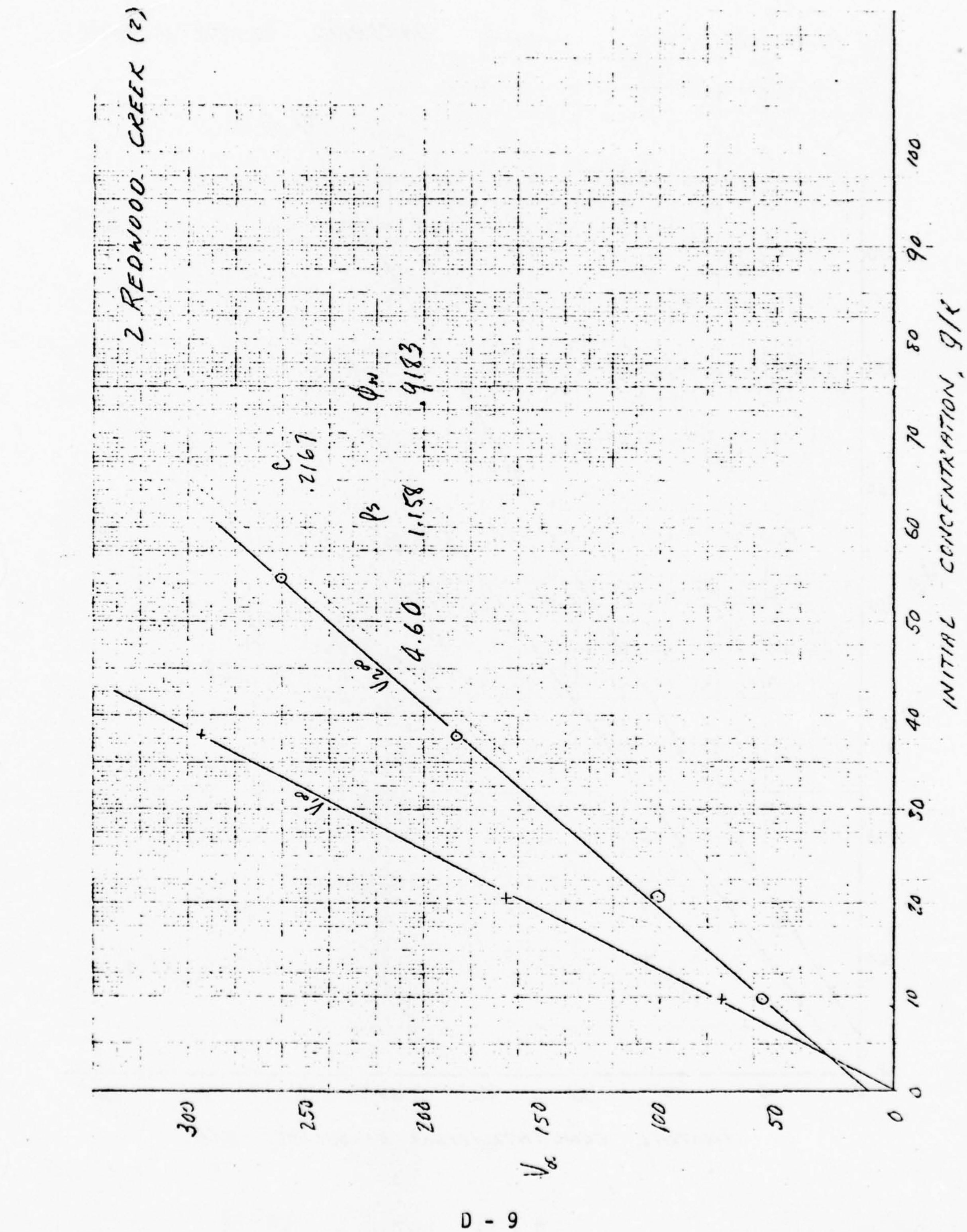
Hindered Settling Test.

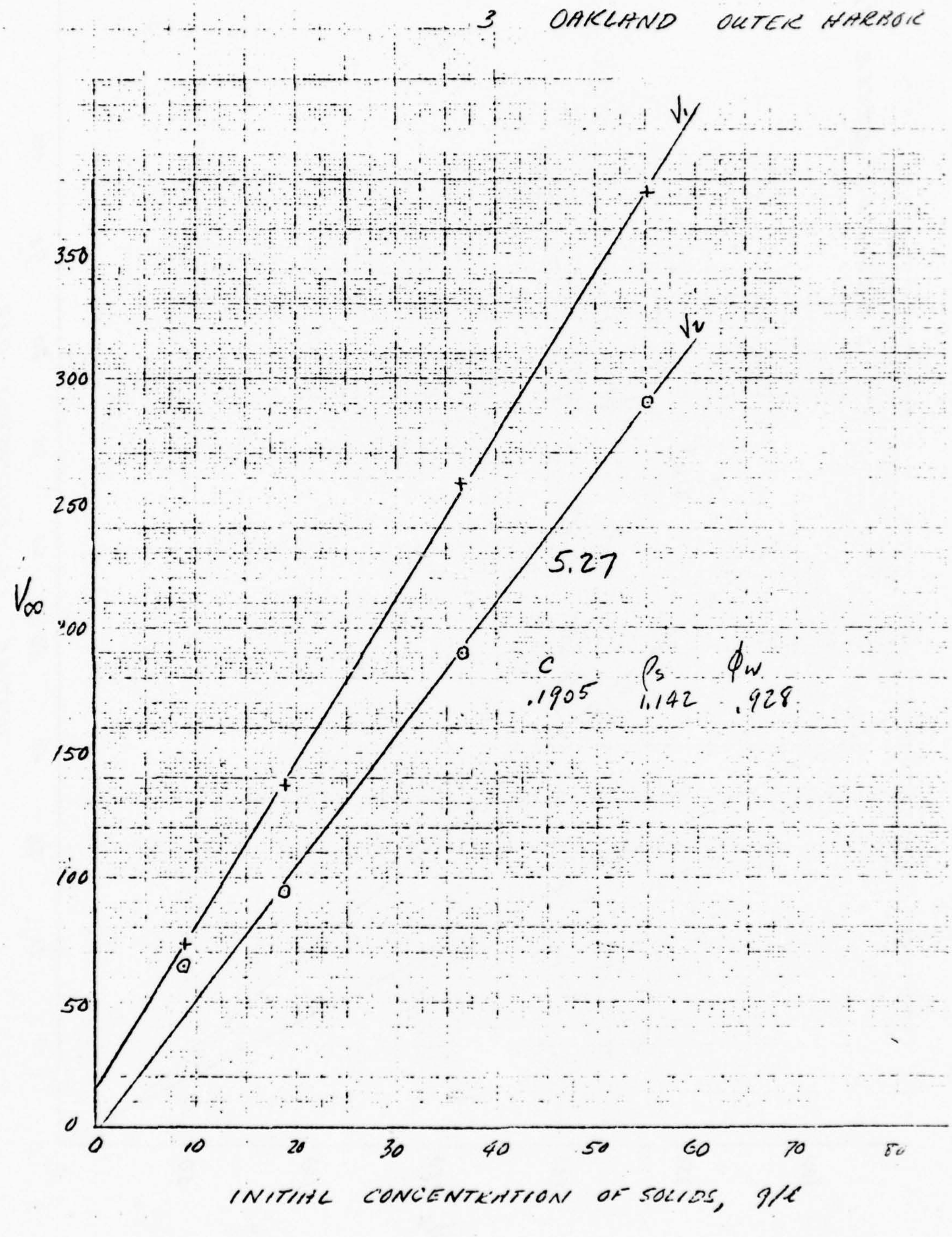


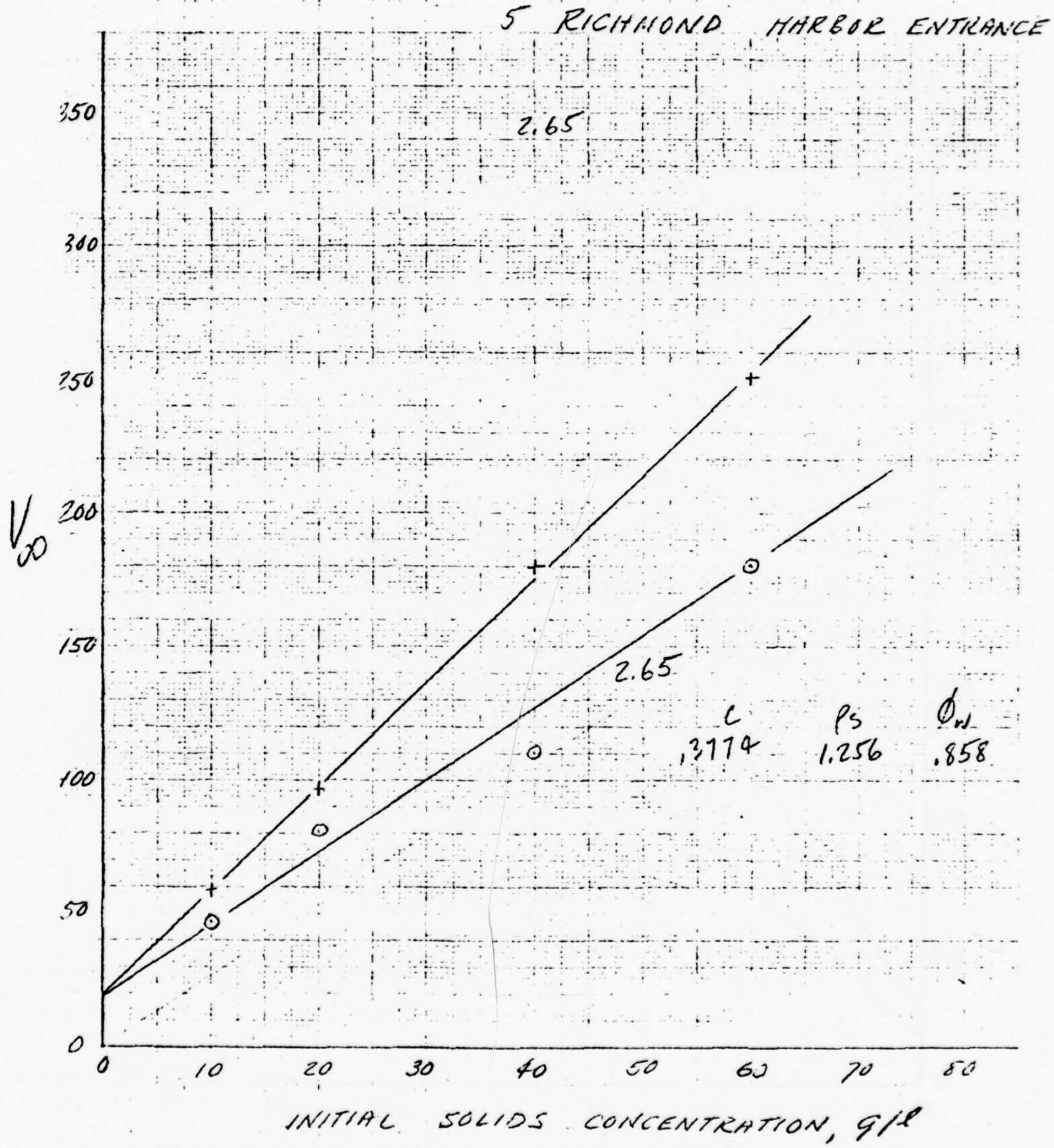
1. SAN FRANCISCO
V_{DO}
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
50
3.47
C= .289
ρ_s 1.203
INITIAL SOLIDS CONCENTRATION, g/l



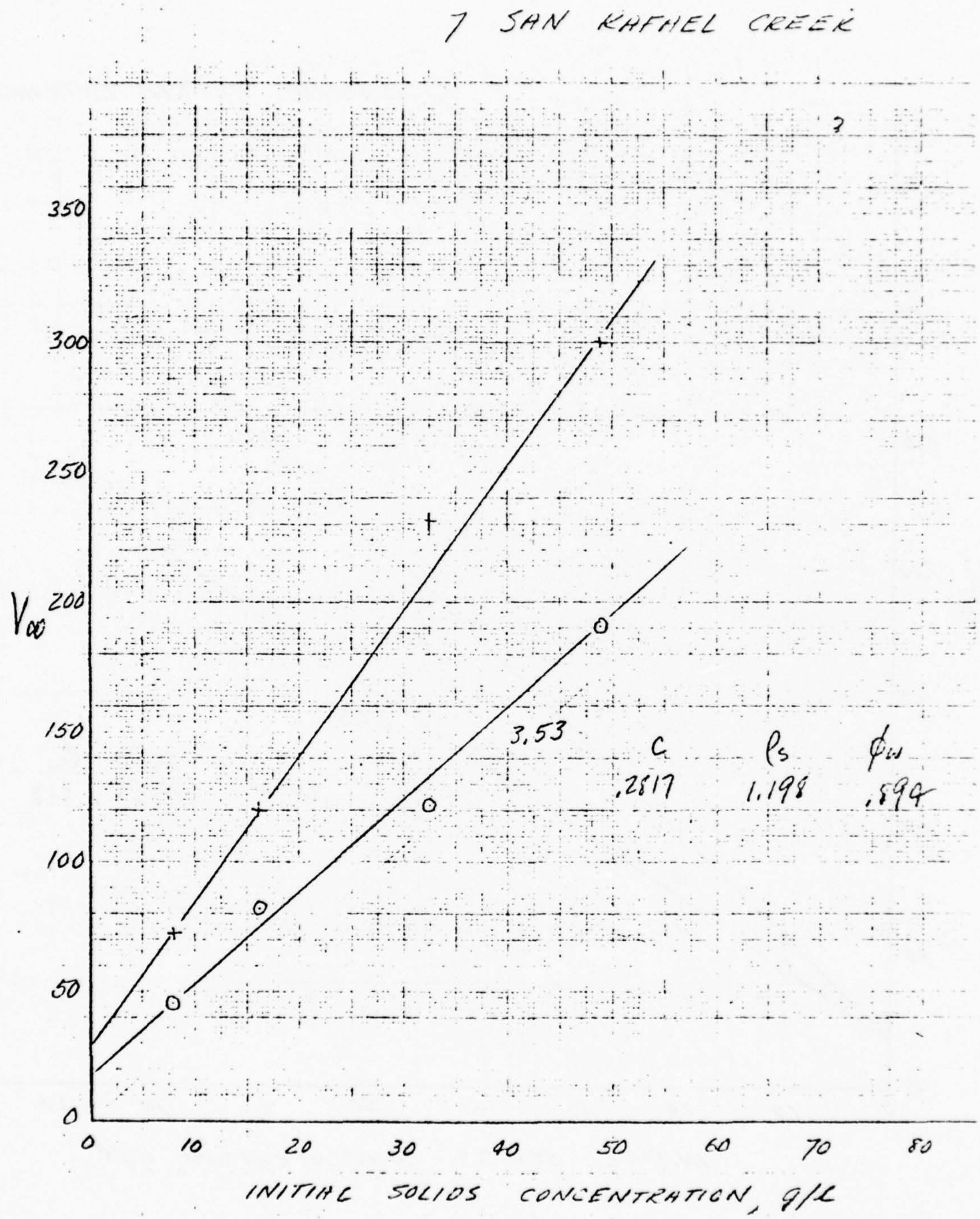
2 REDWOOD CR. (1)
V_1
V_2
5.80
c
ρ_s
ϕ_w
.1780
1.134
.933
V_∞
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
80
INITIAL CONCENTRATION OF SOLIDS, g/l

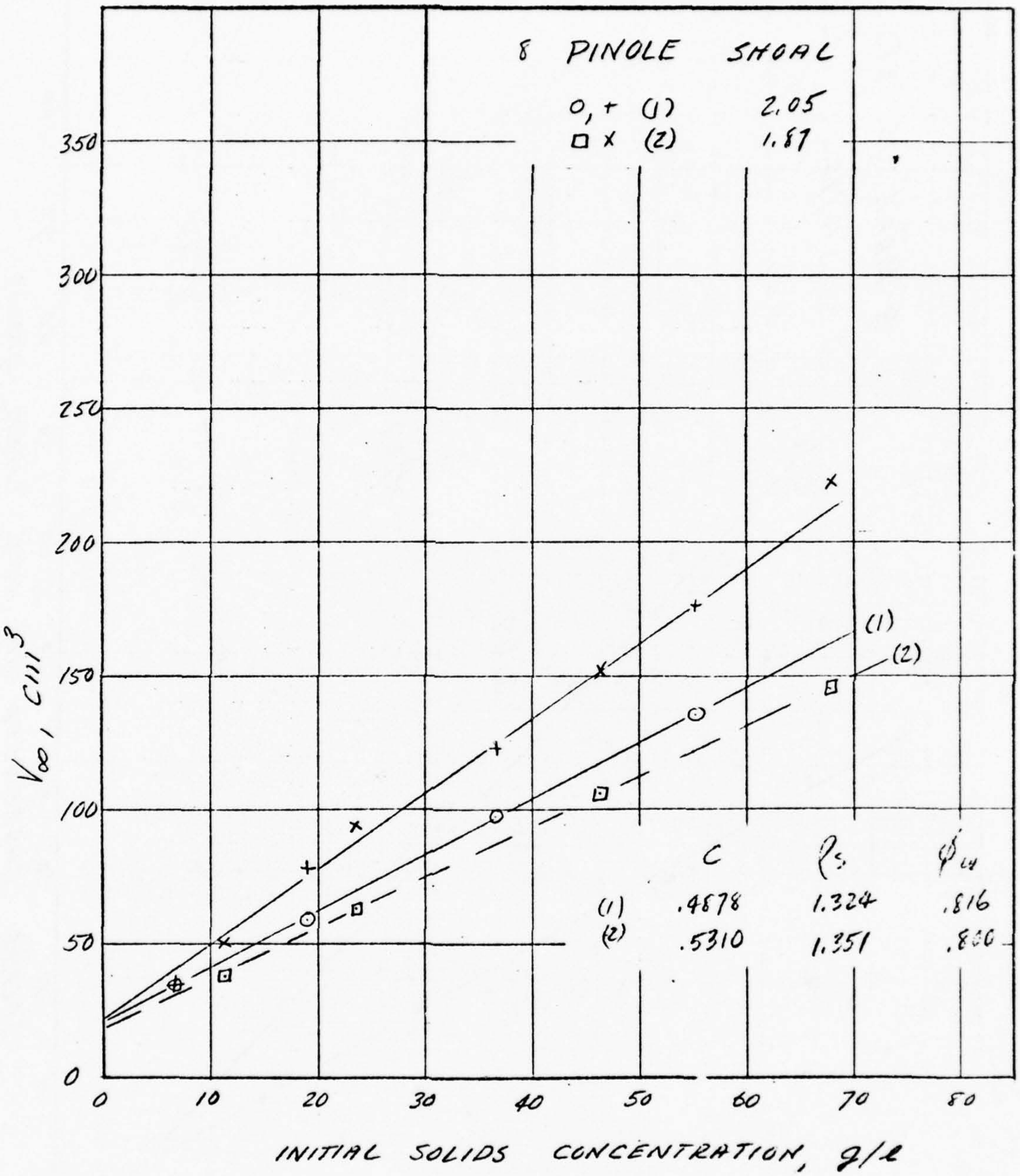

2 REDWOOD CREEK (2)
INITIAL CONCENTRATION, g/l
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
C
.2167
4.60
1.158
.9183


3 OAKLAND OUTER HARBOR
V_1
V_2
5.27
C
.1905
ρ_s
1.142
ϕ_w
.928
V_∞
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
INITIAL CONCENTRATION OF SOLIDS, g/l

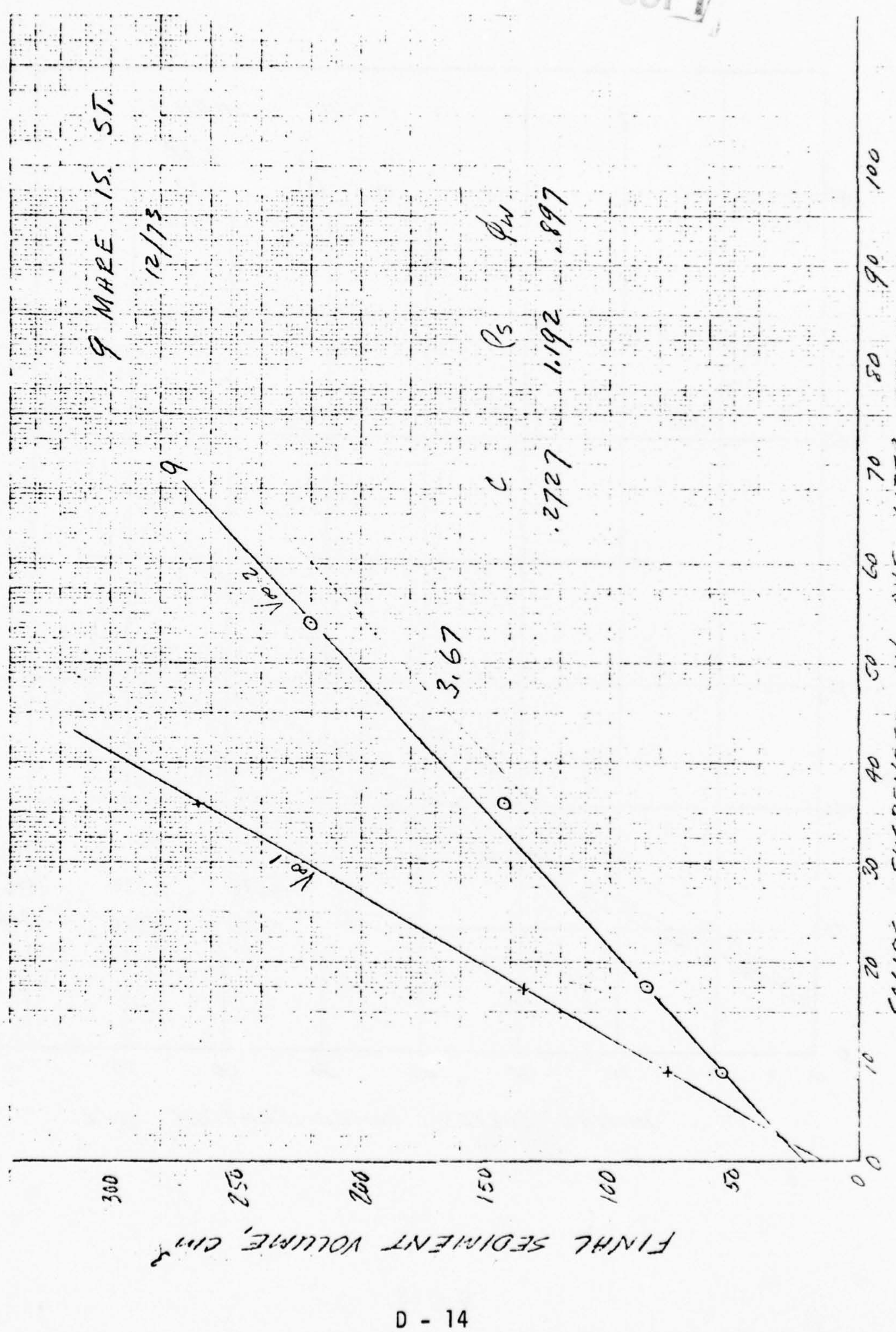


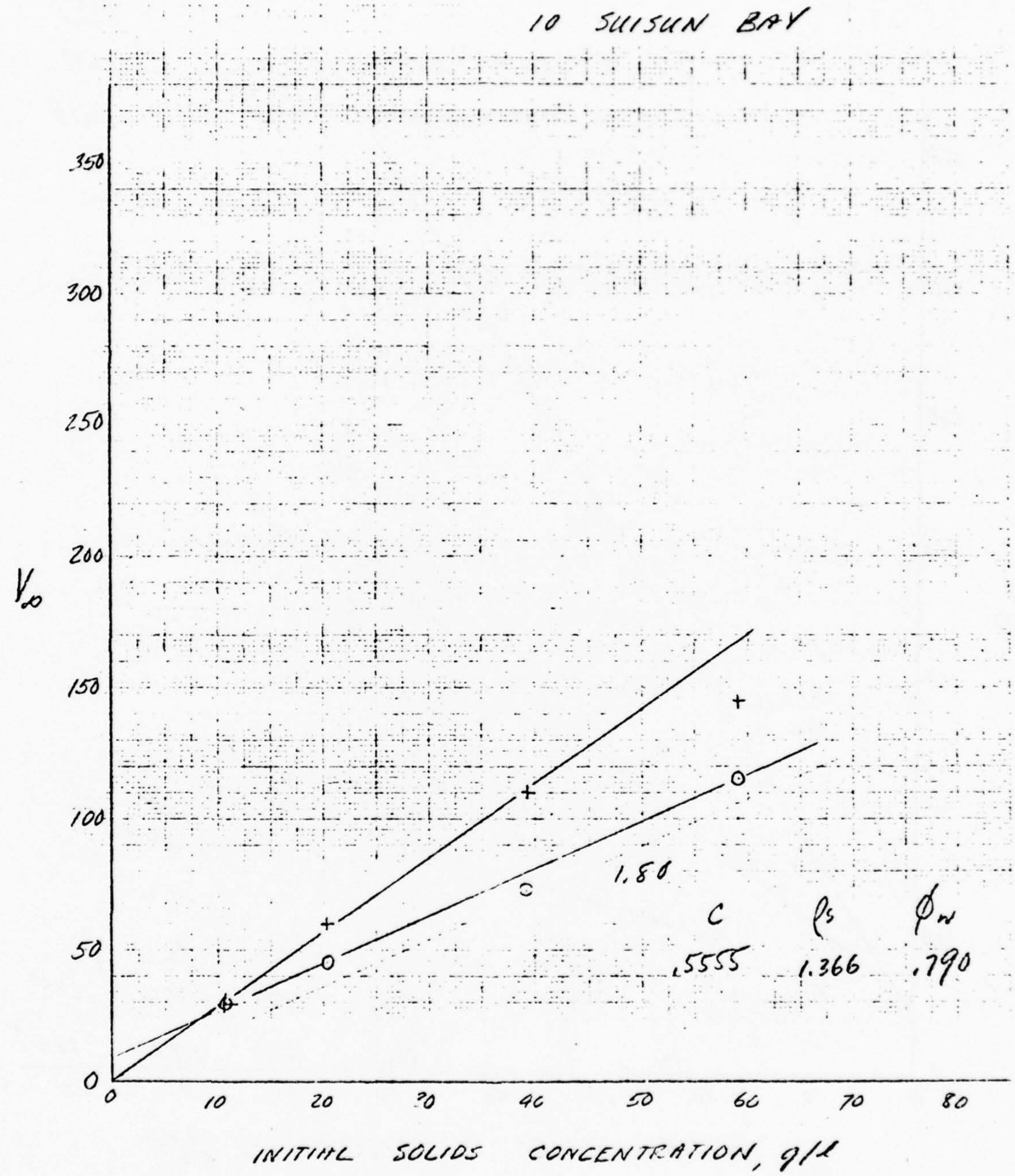
5 RICHMOND HARBOR ENTRANCE
2.65
2.65
C
.3774
ρs
1.256
ϕ_{vl}
.858
V_∞
0
50
100
150
200
250
300
350
0
10
20
30
40
50
60
70
80
INITIAL SOLIDS CONCENTRATION, g/l

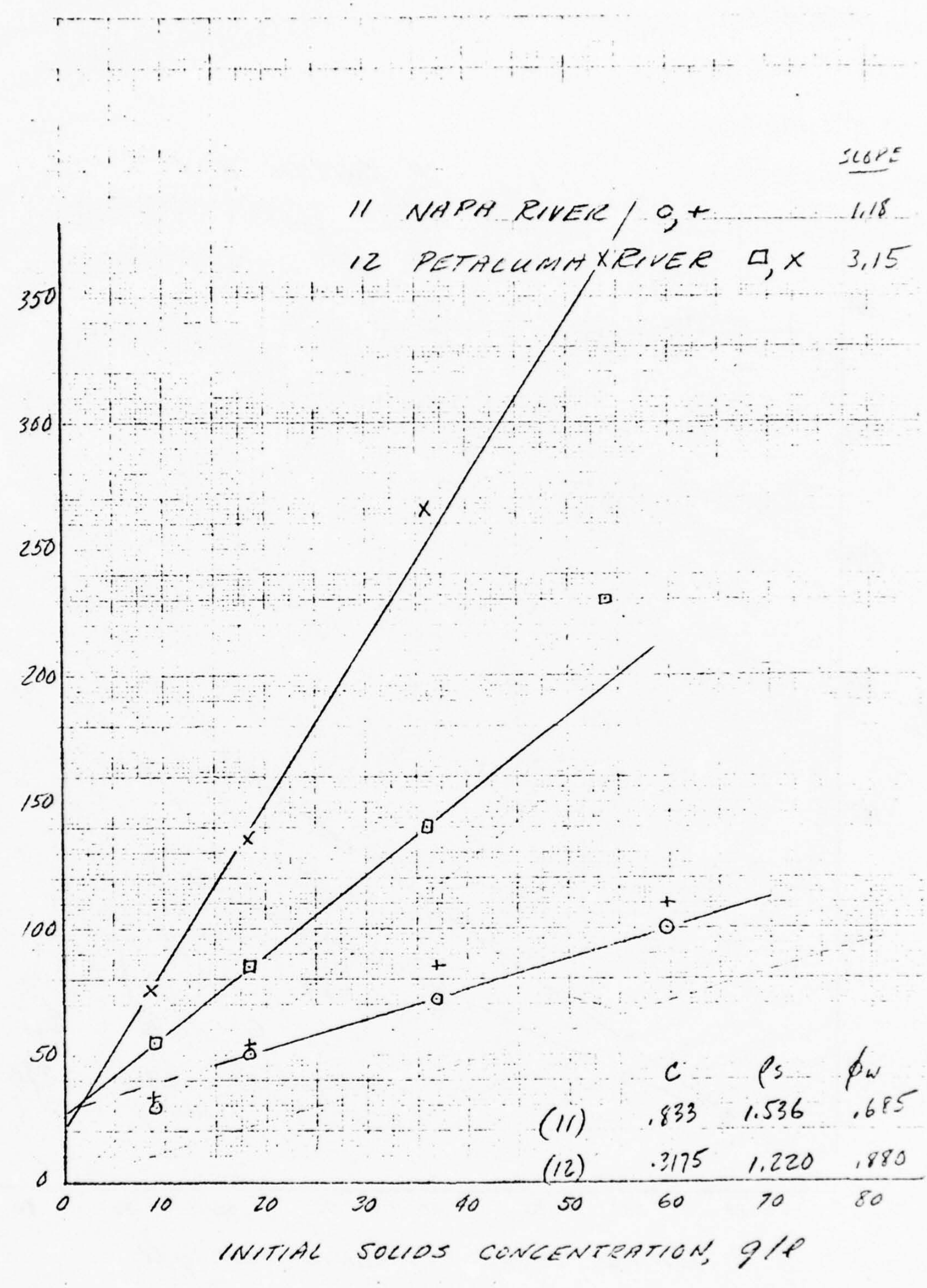

7 SAN RAFAEL CREEK
V_∞
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
INITIAL SOLIDS CONCENTRATION, g/L
3.53
C_i
.2817
ρ_s
1.198
ϕ_w
.599



8 PINOLE SHOAL
O, + (1) 2.05
□ X (2) 1.87
C
(1) .4878 1.324 .816
(2) .5310 1.351 .800
(1)
(2)
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
INITIAL SOLIDS CONCENTRATION, g/l


9 MARE IS. ST.
12/73
C ρs φw
.2727 1.192 .897
3.67
9
FINAL SEDIMENT VOLUME, cm³
SOLIDS SUSPENDED IN ONE LITER, grams
0 10 20 30 40 50 60 70 80 90 100
0 50 100 150 200 250 300


10 SUISUN BAY
V_∞
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
INITIAL SOLIDS CONCENTRATION, g/l
1.80
C
ρ_s
ϕ_w
.5555
1.366
.790



SLOPE
11 NAPA RIVER / ⊙, + 1.18
12 PETALUMA RIVER ⊡, X 3.15
V_∞
C ρs φw
(11) .833 1.536 .685
(12) .3175 1.220 .880
0 50 100 150 200 250 300 350
0 10 20 30 40 50 60 70 80
INITIAL SOLIDS CONCENTRATION, g/l

APPENDIX E

ENVIRONMENTAL CRITERIA

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ENVIRONMENTAL CRITERIA

The following set of criteria for use in assessing the environmental impact of land disposal of dredged material was prepared by the URS Research Company of San Mateo, California.

ENVIRONMENTAL CRITERIA

GENERAL PRELIMINARY INFORMATION

Federal and State Regulations. Every state has its own set of regulations, applying to projects involving construction, discharge or changes in the environment, which require statements of environmental impact. The Federal government will also claim jurisdiction because the contracting agent will probably be the U.S. Army Corps of Engineers, a Federal agency.

Section 102 of Public Law 91-190, the so-called National Environmental Policy Act, requires (1) the EPA to conduct an environmental analysis of projects applying for Federal assistance under provisions of the Federal Water Pollution Control Act, (2) ". . . all agencies of the Federal Government to utilize a systematic, interdisciplinary approach to insure the integrated use of the natural and social sciences . . .", and (3) all agencies of the Federal Government to "include in every recommendation or report on proposals for . . . major Federal action significantly affecting the quality of the human environment, a detailed statement . . ." which includes

(i) the environmental impact of the proposed action
(ii) any unavoidable adverse environmental effects
(iii) alternatives to the proposed action
(iv) the relationship between short-term uses and long-term enhancement of the environment
(v) any irreversible and irretrievable commitments of resources involved in the proposed action.

To accomplish item (i) above, the Federal regulations require that environmental assessments be prepared for all projects. This environmental assessment must contain all information needed for the responsible agency (in this case probably the Corps of Engineers) to prepare an environmental impact statement when deemed necessary. Each state has the option to add more requirements to the statement but cannot delete any. California, for example, requires a statement of mitigating measures proposed to minimize the impact and a statement of the growth-inducing impacts of the proposed action, in addition to the five items listed above requiring detailed statements.

The EPA has, by law or special expertise, the responsibility to comment on the following types of environmental impacts:

(i) Water quality and pollution control

(ii) Air quality and pollution control

(iii) Water supply and water hygiene

(iv) Solid waste management

(v) Radiation problems

(vi) Pesticide use and control activities

(vii) Noise

(viii) Toxic materials

(ix) Herbicides

(x) Land use and management; wetlands, river banks, estuaries, beaches, irrigation projects, highways, reservoirs, forest lands, rural sources of pollution, mining, etc.

(xi) Electrical power generation

(xii) Urban development

(xiii) Industrial development

(xiv) Transportation and handling of hazardous materials.

The purpose of the environmental impact assessment is to provide sufficient information to enable the responsible agency to evaluate the environmental impacts of a proposed project or projects, and to write an environmental impact statement if one is deemed necessary. The EPA does not at the present time set hard and fast guidelines on the format for presentation, the amount of data required, the field sampling program or any other aspect of data acquisition and processing. The attitude of the EPA may vary substantially from project to project regarding the amount of data and the number of subject areas that should be covered. It is advisable for the agency responsible for formulating the environmental assessment to consult closely with the EPA officials responsible for the review. Federal regulations applicable to environmental matters are constantly being revised. All revisions are published in the Federal Register and arranged for relatively easy access in the Environmental Reporter (Bureau of National Affairs, Inc., Washington, D.C.), a publication consisting of several volumes, which is updated periodically.

It is another matter to provide an environmental assessment acceptable or informative to the general public. Generally the public wants to be informed about the potential adverse impacts but wants also to see an overall assessment of the costs and benefits. The cost/benefit ratio has historically been extremely difficult to calculate whenever

the costs involve aesthetics and other intangibles. This drawback to the cost/benefit ratio technique of assessment is slowly being overcome. Procedures for evaluation of the economics associated with intangibles are being formulated and examined. One such attempt at a technique for dimensionless analysis of the costs and benefits has been proposed in a small pamphlet entitled Environmental Impact Assessment: A Procedure, (Ref. No. 97). Problems always arise in using these methods when one attempts to assign value judgments as numerical weights to indicate the relative importance of each impact. The technique also has a more basic flaw in that scientific considerations are more numerous than economic ones, causing an imbalance in the weighting of scientific and economic impacts.

As already indicated, however, the environmental assessment generally must satisfy the requirement of sufficient information to write the environmental impact statement, but there is no set procedure for obtaining this information. It is the responsibility of the agency contracting for the assessment to carefully define the scope of work. A representative sample of subject areas covered in environmental assessments is presented in Table 1. Each subject area overlaps somewhat with another in most cases. Aesthetics overlaps with virtually everything if taken in its broadest sense, because aesthetics is usually synonymous with both public well-being and public health and safety. Any discussion within each area should be limited to factual information and a professional estimate of the potential impacts of the proposed project upon that subject area.

Format for Discussion of Assessment Procedures. An ideal environmental assessment would address each topic listed in Table 1 for each proposed site. The land disposal of dredge spoils in the Bay area involve occurrence of the following events:

- Large quantities of dredged material from a number of locations in the Bay will be transported from the dredging site. This involves the use of heavy equipment, barges, the employment of a substantial work force, and certain hazards associated with the transport of the dredged material by barge or pipeline.
- Alteration of the land form of the proposed land disposal site or sites, with consequent changes in potential and actual land use at the site, natural drainage patterns, changes in the degree of access, and so on.
- Actual disposal of the dredged materials on the site, with potential effects on a number of environmental parameters including habitat changes for the resident biotic population, air quality, water quality and aesthetic value. The magnitude and extent of these impacts will be different during the actual period of deposition and after filling of the site has been accomplished.
- There will be a number of impacts of the dredging operation on the socioeconomic condition of the San Francisco Bay area, which impacts are inextricably linked to the existence of an approved method of disposal of dredge spoils. As such, the

dredging operation itself and the costs and methods of spoil disposal have a demonstrable though indirect relation to a number of socioeconomic parameters.

Each of these events creates a corresponding set of environmental impacts; each such impact must be adequately addressed in the environmental impact report in order to achieve compliance with existing legal requirements.

The information supplied in subsequent sections of this report relates specifically to procedures for assessing the impacts of the land disposal of dredge spoils on terrestrial sites. These descriptions are presented in decimal format numbered sequentially. Under each topic, the following items will be discussed:

(i) Overall approach to evaluating the impact.

(ii) The minimum baseline information and projection required.

(iii) Expertise required in the personnel to recognize and evaluate the impact.

(iv) Specific parameters to look for.

(v) Impacts which generally cause the most public concern.

Table 1

SUBJECT AREAS TO BE COVERED
IN
ENVIRONMENTAL IMPACT ASSESSMENTS

---

1. Climatology

   Temperature, rainfall, humidity, localized microclimates or conditions.

2. Hydrology

   Water supplies, stormwater runoff characteristics.

3. Air Quality

   Particulates, nitrogen oxides, oxidants, hydrocarbons, CO.

4. Water Quality

   BOD, COD, nutrients, trace metals, toxic chemicals, total salts, hardness, physical characteristics, odors.

5. Geology

   Formations, groundwater aquifers, surface features, unique areas, scarce resources.

6. Terrestrial Biology

   Habitats, existing species, life cycles, food supplies, rare and endangered species.

7. Aquatic Biology

   Planktonic, nektonic, and benthic populations, interrelationships between biological elements and the physicochemical environment.

8. Archaeology

   Known archaeological sites, prediction of areas where sites are likely to occur, list of arachaeological institutions in the area.

9. Aesthetics

   Recreational facilities, open space, freedom of movement, noise.

10. Noise and Traffic

Table 1
(cont'd)

SUBJECT AREAS TO BE COVERED
IN
ENVIRONMENTAL IMPACT ASSESSMENTS

---

11. Public Health

Infectious diseases, toxic metals.

12. Land Use/Population/Economy

Distribution of land use and population, zoning, provisions of master plan, socioeconomic impact of proposed action.

SUBJECT AREAS

1. Climatology

Introduction

The climatic impacts of any major construction project/development can be significant under certain conditions. Major climatic impacts can be attributed to water impoundments such as a dredge spoil site. Other climatic impacts can be caused by the construction of any structures that can alter patterns of local airflow. The associated impacts are generally local in nature.

Impoundments generally change local humidity (increase), temperature (less extreme), winds (stronger) and fog (increase). Changing the airflow can cause the local storage or reduced retention of colder air. No major changes are usually attributed to construction (short-term) practices, but the impounded water and airflow changes could persist for the effective life of the site.

Minimum baseline information

Minimum climatic baseline information should include, but not necessarily be limited to:

Summaries of available information recorded at existing weather stations in the immediate area and for the region, especially wind direction, wind speed, atmospheric stability (lapse rate), minimum, average and maximum temperatures, precipitation, snowfall, fog, etc. This information should be summarized in a format to be usable in the air quality consideration. The stability, wind speed and wind direction should be analyzed for concurrent occurrences. It is best to present as many occurrences as possible,

broken down for time of day, season, and yearly average. An example is presented in Table 2. The available weather summaries usually do not have concurrent frequencies, and the original data must be reduced. The stability information can be obtained by using Pasquill's Tables (Turner, 1969), based on solar insolation, cloud cover and wind speed, which are usually given.

If sufficient information on the local area is not available, baseline climatic data can sometimes be extrapolated from about 30-days field data from a portable weather station. Long-term records should be available from an adjacent area. The short-term results should be compared on an hourly (up to four hour) basis to the long-term station's data. It is usually possible to make long-term approximations of the climatic conditions at a specific site using these comparisons.

The expertise required can be supplied by almost anyone familiar with the subject. If a meteorologist or air quality engineer is not conducting this portion of the study, he should be supervising those who are.

The impacts which cause most public concern would probably relate to the more severe nature of the weather, or to changes which may cause economic impacts. Both these impacts could be caused by temperature and possibly wind modifications. Increased fog can cause a localized safety hazard.

- Many documented cases exist of the climatic modifications induced by urban growth. These are given in the bibliography. For examples of climatic changes consult Black and Tarmy (1963), Aynsley (1969), Nakajima (1973), and Estoque and Bhumralkar (1971).

- Resource expenditures to compile the baseline data and investigate possible impacts depend largely on the scale of the project area and amount of existing data. Assuming the availability of the data, and only one station is present in a fairly small study area (small meaning no large variations in local weather patterns), the reduction of data may require about one man-week. The impact prediction should be able to be completed in about 1-1/2 to 2 man-weeks. If field data collection is required, the use of a weather station for 30 days would cost about $350, plus set-up time and field checks. Another man-week would be required to compare the field results with a "nearby" long-term station and make the necessary extrapolations. These estimates assume that the data is readily available. Travel to set up the station, take down, plus necessary security of the instrument, would be additional, depending on the location and area.

2. GROUNDWATER HYDROLOGY

Introduction

The purpose of the groundwater hydrology study will be assess the potential interrelationships between land disposal of dredge spoils and groundwater hydrology under the following major headings:

1) impact on groundwater quality of the impounded dredge spoils.

2) impact of groundwater hydrology on the overall suitability of the site (including potential for subsidence, horizontal movement, etc.) for the safe disposal of dredge spoils.

Few specific difficulties are expected with regard to the effect of the dredge spoils on groundwater quality for at least the following reasons:

a) most of the potential sites are adjacent to portions of San Francisco Bay. This implies that few if any sites will be situated between the major points of aquifer replenishment and points at which an aquifer is tapped either for production of agricultural or domestic water.

b) the characteristics of the dredged material itself tend to preclude infiltration of water associated with the spoils into subsoil layers, thus reducing the likelihood of any demonstrable effect. Further, the disposal sites are not likely to be placed at locations of importance in the recharge of major aquifers, another reason for expecting the impact to be minimal

Groundwater hydrology may have an effect on the suitability of certain sites as disposal areas, particularly in the case of any island sites in

in the Sacramento delta region. In the case of these sites particularly, the complex of factors which characterize the geology and groundwater hydrology of the region will have to be investigated in some detail.

In general, however, groundwater hydrology is not expected to be the focus of many significant negative environmental impacts.

Baseline Data

In evaluating the hydrological impacts of a specific site, the following general information should be sought:

- Area and boundaries of watershed
- Percent of impervious surface within watershed
- Topography and slope characteristics of watershed
- Soil types
- Soil cover
- Flow characteristics of main drainage channel and its tributaries
- Rainfall characteristics of the general location
- Historical floodplains
- Actual and potential use of subsurface water for agriculture and domestic purposes

3. AIR QUALITY

The air quality impacts associated with land disposal of dredge spoils would be caused by fugitive dust losses and any on-site heavy equipment vehicle use. There is also the potential for production of undesirable odors, particularly during the initial deposition of reducing sediments. These odors should be of a temporary nature and can probably be effectively controlled by proper management of the disposal operation. Fugitive dust losses would increase as the material dried, but significant losses could be evident shortly after placement of the spoil. As vegetation begins to become established on the new material, dust losses would decrease to more "natural" levels. It may be desirable to move the material after initial placement. If this is to be done using heavy duty equipment, the vehicle emissions could be substantial depending on the number of vehicles needed. Vehicle activity on the site would also increase dust losses due to added surface disruptions.

An information questionnaire should be completed for each alternative site for comparisons of air pollution impact potential. This questionnaire includes information in four major areas; ambient air quality, source emissions, dispersion potential and receptor locations. This matrix follows in a rough form:

I. AMBIENT AIR QUALITY

A. Location of Closest Air Quality Monitoring Station

1. Distance _____ meters

2. Direction _____ °

B. Monitored Air Quality (Last Complete Year of Records)

	Annual Average Concentration	Peak Hour Concentration	Month of Peak Hours	No. of Times Standards wer Exceeded for Year
1. Particulates				
2. Oxidants				
3. Carbon Monoxide				
4. Sulfur Dioxide				
5. Oxides of Nitrogen				
6. Hydrocarbons				

C. Close By Major Sources (from source inventory)

emissions in tons/year

name, distance, direction, part, CO, SO_2, NO_x, HC

1.

2.

3.

4.

II. SOURCE EMISSIONS

A. Fugitive Dust

1. Amount of spoil placed, _____m^3

2. Acres covered per year, _____

3. Method of movement of spoil on site, after initial placement:

B. HDV Emissions

1. Number of vehicles on site at one time (average) ____, year ____

2. Total hours of vehicles on site per year _____hrs

3. Any transport of material to or off site using trucks? If so, describe trip length and number/year

III. DISPERSION POTENTIAL

A. Topography, Confined, Gentle or Flat

B. Winds

	N	NE	E	SE	S	SW	W	NW
1. Annual Frequency of Direction of Speed								
2. Frequency of Direction and Speed for "worst" months								

C. Mixing Volume by Month (miles/month average velocity x mixing height)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1. Average day													
2. Average night													

IV. RECEPTOR LOCATIONS (within 5 miles)

	Distance	Direction
A. Closest Urban Activity		
B. Closest School		
C. Closest Hospital		
D. Closest Wildlife Area		
E. Others		

After this information is collected, methods must be devised to directly relate one site against another. For this purpose, very general rating systems may be used. Some of the information would be used directly in this analysis, while others are for assessing the accuracy of the procedure. Each major area would eventually have a rating. These are hypothesized as follows:

I Ambient Air Quality

AAQP = number of times particulate standards are exceeded per year

AAQG = number of times $O_x + CO + SO_2 + NO_x + HC$ standards are exceeded each year

II. Source Emissions

$$SEDNST = (\text{acres covered per year}) \times (\text{annual average wind speed})$$

$$SEVEH = (\text{total hours of vehicles on site per year}) \times \left(\frac{1}{\text{annual average wind speed}}\right)$$

III. Dispersion Potential

MVD = annual average daytime mixing volume

MVN = annual average nighttime mixing volume

IV. Receptor Locations

$$RU = \left(\frac{\text{frequency of wind towards direction}}{\text{distance to urban activity}}\right)$$

$$RS = \left(\frac{\text{frequency of wind towards direction}}{\text{distance to school activity}}\right)$$

$$RH = \left(\frac{\text{frequency of wind towards direction}}{\text{distance to hospital activity}}\right)$$

$$RW = \left(\frac{\text{frequency of wind towards direction}}{\text{distance to wildlife activity}}\right)$$

$$RO = \left(\frac{\text{frequency of wind towards direction}}{\text{distance to other activity}}\right)$$

These values will be further refined to reflect more important local problems. They will be used as an indicator of what areas should be investigated in greater detail if needs be.

Table 2

AN EXAMPLE OF A FORMAT
FOR
PRESENTING CONCURRENT OCCURRENCE OF WIND AND STABILITY
(Winter Morning)

STABILITY*	C	D	E	F	TOTAL
NW Wind					
0 → 1 m/sec	0	1	5	0	
1 → 3 m/sec	0	3	3	0	
3 → 7 m/sec	0	1	2	0	
> 7 m/sec	0	0	0	5	
	0	5	10	5	20
SW Wind					
0 → 1 m/sec	1	1	3	0	
1 → 3 m/sec	2	3	10	7	
3 → 7 m/sec	1	5	10	3	
> 7 m/sec	1	1	2	0	
	5	10	25	10	50
W Wind					
0 → 1 m/sec	2	1	3	4	
1 → 3 m/sec	1	1	10	1	
3 → 7 m/sec	1	1	2	0	
> 7 m/sec	1	2	0	0	
	4	4	15	5	30
TOTAL	10	20	50	20	100

* Stability designations refer to atmospheric stability: A is least stable (low pollution potential) and F is most stable (high pollution potential).

4. WATER QUALITY

Introduction

Alterations in the existing ecosystem can cause unexpected changes in many areas, one of which is water quality. Water is a mixture of the basic compound H_2O and an enormous number of chemical constituents, non-living detritus and microscopic and macroscopic biota. Scientists measure only a few of the components of this mixture to ascertain the "quality" of the water. The existing water quality is determined by the existing ecosystem -- which includes production and consumption, uptake and discharge, grazing and being grazed upon -- the arrangement of the ecological niches. There are several recently published examples of the changes in the common measures of water quality caused by changes in the common measures of water quality caused by changes in ecosystem structure. Brooks (1969) noted that choking phytoplankton blooms in a lake were reduced when the fish population was killed. The reason was that fish preyed upon larger zooplankton, leaving only smaller zooplankton. The zooplankton in turn grazed only upon phytoplankton of a definite size range. Elimination by predation effectively eliminated grazing upon one size range of phytoplankton which quickly accumulated a substantial biomass. Brinkhurst (1972) found that sludge worms in sediments of areas in Lake Erie effectively cause a complete turnover of nutrients, thus continually stimulating phytoplankton growth. Pfister, et al. (1973) found that particulate material -- in their experiments only clays -- adsorbed to enzyme substrates and bacteria, thus stimulating bacterial activity in aqueous solutions. Finally,

Rhee (1972) found that bacteria and algae compete for available phosphate when growing, and bacteria are more successful to the extent of subduing algal growth altogether.

At the present time, these types of effects are not recognized by EPA as causing significant impacts upon the water quality. This lack of recognition is not justified by data but caused more by a lack of methods to observe the parameters.

The personnel most likely to recognize and comment upon the possible impacts on water quality of changes in the structure of the ecosystem would have strong tra_ning in ecology, biology, and chemistry, with some experience in graduate work.

The researcher might require a thorough baseline description of the existing ecosystem in the water body in question, including phytoplankton, zooplankton, and bacterial counts. This type of data is well beyond the range of most studies and is extremely expensive to acquire. The complexity of ecosystems far exceeds present capabilities to understand them fully.

The greatest public concern arises from visible and odorous indicators of poor water quality. Choking algae blooms, dead fish or hydrogen sulfide (rotten egg) odor are apt to raise the greatest outcry. Increase in dissolved trace metal concentrations decrease will be noticed sooner by the public health department.

This kind of complex secondary ecological effect upon water quality is presently recognized in the research literature and conclusions are still extensively debated. Any discussion here of comparable case

studies other than those indicated earlier would only invite debate. Nevertheless, it is apparent that changes in the structure of the ecosystem may cause temporary or recurring undesirable changes in the water quality. For example, referring to the four studies mentioned above, several undesirable events might logically occur in each case. An increase in the algal concentration caused by an increase in the fish population could lead to choking blooms, high BOD and COD, and, eventually, a fish kill due to low oxygen conditions in the deeper layers of the lake. Sludge worms causing the release of materials from sediments could result in perpetually poor water quality in the lake despite efforts to improve the quality of wastewater. Decreases in suspended particulate matter concentrations could decrease the suspended bacterial population, causing an increease in phosphate concentrations which then may stimulate algal growth. All of these sequences are highly speculative but may quite legitimately be recognized as potential problems.

Ascertaining the extent and significance of these hypothetical problems will involve a great deal of field research, conceivably a major effort of several tens or hundreds of thousands of dollars. This type of work is best carried out by an academic research institution or a consulting firm with extensive practical experience in this field.

Short-Term (Construction) Impacts

The construction-related impacts upon water quality are due almost exclusively to erosion of the freshly turned earth. The only parameter

affected significantly is the turbidity or suspended solids concentration. The only occasion when this may not be true is when the operations uncover land fills originally established for the disposal of toxic or noxious materials, sludge or trash. In this case, the runoff water from the site could contain concentrations of BOD, COD, or trace metals in excess of the generally accepted drinking water or municipal water standards. These standards are available in three published documents: Public Health Service Drinking Water Standards (1962); International Standards for Drinking Water (1971); and Water Quality Criteria (1968).

Baseline Data

Although no set amount of data is required, it is advisable to estimate the erosion potential from the construction site and predict the order of magnitude of the additional solid matter input to surface waters. If the estimate of the worst possible input is well below the existing solid concentration, a negative declaration (a statement of insignificant impact) can be made. If the potential input is significant, further detailed work is necessary to refine the prediction. The proposed construction site should be inspected, and all available records on the site reviewed to determine whether the site has been used for land fill or solid waste disposal. Presumably this kind of detailed historical information will be acquired by the design firm. A historical record of the site is always discussed in the environmental assessment.

The staff responsible for evaluating this potential impact should have general training in chemistry and geology. No advanced graduate training should be necessary.

The erosion potential can be estimated from the slope, aereal extent of the site, and erosion data from similar areas. For most soils, the universal soil-loss equation, as discussed by Wischmeier & Smith (1965), will be applicable. Erosion estimates should be carried out in consultation with local experts. The physical characteristics of the soils will be determined by the designer. The chemical composition should also be determined to estimate the potential pollutional effect of the eroded material. A typical analysis would include measurement of the following parameters: BOD, COD, soluble phosphate and nitrates, total phosphorous and nitrogen, several trace metals including Hg, Cu, Ni, Zn, Fe and Mn, in areas that have been heavily dosed with pesticides, an analysis for chlorinated hydrocarbon and standard bacteriological analyses.

The erosion-related impacts which cause most public concern are usually visual or odorous, but significant mortality of shellfish or freshwater benthic organisms can also cause concern. Fish kills can be caused by high silt loads, low oxygen concentrations resulting from the silt load, or the incorporation of toxic materials from the silt into the fish. Low oxygen concentrations cause the odor of hydrogen sulfide. High turbidity will cause public concern if the condition is uncommon.

The time and money required to evaluate the potential impact are small. A complete chemical analysis of a single soil sample costs in the neighborhood of $100 to $200. Usually no extensive study need be conducted because soil analyses data typical of the site are available from some local or published sources such as the U.S. Geological Survey, Department of Agriculture, or state universities. It is merely necessary to verify that the

specific site is not greatly different from the general area. The calculations and estimates needed to approximate the solids load and pollutional load are simple and rapidly completed.

Impacts To Be Addressed

The water quality impacts can be addressed in four separate sections. These include:

1. Sources of water
   - rainfall
   - dewatering
   - infiltration
2. Mechanism of pollutant transfer
   - leaching of soluble and insoluble material
   - long-term dissolution of pollutants
   - anoxic conditions and resulting pollutant solubility
3. Paths of pollutant transport
   - infiltration
   - overland flow
4. Receiving water
   - groundwater
   - surface water

Included within these groups are variables associated with a specific site or specific spoil. Some of these include:

- moisture content of spoil
- soil type and depth
- depth of impermeable layer
- depth to groundwater
- uses of groundwater and location of use

direction of groundwater flow

rainfall history

ground surface slope (before and after fill)

spoil chemical composition

organic matter

clay fraction

iron and manganese concentrations

trace metal concentrations

organohalogens

surface drainage network description

path of flow

intermittent or continuous "streams"

physical properties of spoil (erosion potential)

engineering parameters to mitigate WQ problems (dikes, ditches, membranes, treatment, etc.)

chemistry of receiving water

solubilities of pollutants in spoil if discharged to receiving water

The water quality impacts associated with spoil disposal operations are a function of many parameters and potential impacts can vary tremendously between sites.

5. GEOLOGY

Introduction

Geologic effects from and upon placement of dredged materials in land disposal areas primarily involve the weight of material upon underlying substrates and indirect effects on adjacent areas and the potential for movement of the material with and without seismic loading. Secondarily, consideration of geologic resources (sand, gravel, economically valuable clay, stone, and other typical exploited mineral resources) should contain land disposal to areas of clearly designated low value. In general this will be accomplished by costs of the large areas required by disposal, although purchase by non-federal agencies or groups and long-term leases for disposal may hinder realistic consideration for valuable common geologic resources.

Criteria or Guidelines for Site Evaluation

Influence of the disposal area on the geology

- Character of underlying strata
  - Depth to bedrock and distance and direction to surface exposure of bedrock
  - Direction and slope of bedrock surface
  - Distance surface or subaqueous slope of greater than 25%
  - Number of distinctive sand and clay-silt strata
  - Geographic distribution of significant clay strata
  - Competence of clay-silt strata
- Depth to ground water

Character of disposed material

Clay and organic content of material

Percentage of water (degree of conditioning)

Proposed depth of disposed material at completion

Project character

Total area and number and area of cells

Cross-section size and distribution of levees

Sequence of disposal among cells

Influence of the geologic context upon the disposal area

Distance to any significant fault (large displacement, considerable length, frequent seisms, etc.)

Predicted repeat interval and magnitude of seisms along faults within 10, 25, or 50 miles.

6. TERRESTRIAL BIOLOGY

Wildlife

Land disposal of dredged materials (normally fine grained and partially organic) requires large areas (hundreds of acres or square miles) because of the volume of spoil produced in typical dredging operations. Typically, the disposal areas will consist of several ponds separated by a series of levees but connected by control gates or wires.

Terrestrial impacts of land disposal arise in conjunction with three major phases: 1) construction of the disposal ponds, 2) the characteristics of the ponds during filling, and 3) the final use of the disposal areas at completion. Significance and degree of impact construction of land disposal ponds will depend upon composition and quality of the wildlife and supporting vegetation (habitat) within the proposed construction, their vicinity and regions. Within areas of uniform composition and quality, differing methods of construction and the design of ponds, as well as differences in methods of and discharge of effluents, can induce radically different impacts of widely varied significance. Disposal schedules, volumes, and conditioning of sediments and methods of conveyance to the ponds will create impacts upon the vegetative colonization and succession processes in the pond areas, the often highly mobile supported wildlife in adjacent areas (especially birds). Upon completion of filling of the ponds, the physiography and prior conditioning of the fill and potential or realized land use will affect both the rate and degree of reintegration of the disposal area into the balance of the regional ecosystem.

Intricate relationships or interactions of the biota within itself and with the physiochemical environment create innumerable difficulties in estimating future responses of the biota to undisturbed or induced conditions, and in determining the significance of differences between undisturbed and induced biotic conditions in the future. Typical time and financial restraints require that description and interpretation of existing and future undisturbed or induced biota must be scaled and balanced in accordance with the importance of potential biotic impacts compared to available resources and potential impacts upon other aspects of the environment. Therefore, a scale of effort and resolution must be recognized (particularly clarified by the February 15,1974 CEQA guidelines).

Biologic investigations can be scaled in a variety of ways to provide a greater or lesser degree of resolution, reliability, and accuracy (with substantial differences in cost). The most general methodology involves the study of lifeforms (e.g., forests, grasslands, chaparral, shrublands, reefs, mudflats, marshes, etc.) and, as in the taxon specific methodology described later, can be applied at the theoretical, compositional, structural, and process (or dynamic) levels of resolution. An additional element of consideration arises with temporal intervals (a list of species or lifeforms may or may not include those volant migrants bats and waterfowl or the climax or subclimax of an existing pioneer grassland). The following outline will provide the guidelines for analyzing the impact of land disposal of dredged materials upon terrestrial wildlife (including all birds) and biota in general using the different methodologies and levels of resolution.

Some general aspects of the environment can be determined from theoretical considerations or the study of lifeforms, but current practice, public policy and the general recognized importance of wildlife require more detailed taxonomic determination of the animals and plants on the proposed project area. Presentation of this data typically consists of a list of the genus and species and common name (the latter is most commonly used in bird lists). Once these names are provided the animals may be resystematized for other formal or informal uses that may be important to future commercial or scientific studies of the site. The taxonomic names also provide the key words for literature searches of regional, distributional, general ecologic, and behavioral information which may be useful in determination of additional problem areas, habitat requirements, or stress tolerances.

The next gradient step yielding additional resolution requires an analyses of the specific distribution of species within the project area and adjacent territories. This is generally presented in the form of a map of the distribution of organisms within the project area. Such maps are most commonly prepared for plants which are fixed and slowly change through colonization and succession, but are more difficult for the mobile animals (amphibians, reptiles, birds, and mammals) most commonly deemed most significant. The dependence of wildlife on specific vegetation lifeforms permits a general correspondence of wildlife distribution with that of vegetation. However, many animals must perform numerous activities and may, therefore, be found in differing habitats during the day or night (e.g., nesting and feeding habitats) and during different seasons. This difficulty most generally affects studies of birds rather than mammals. Often a bird list of the

entire project area may be supplemented by a map locating fixed points of use (roosts, nests, watering areas, and particularly well used feeding ground). Interpretative information of food chains or webs (trophic structure) may be derived from the composition and distribution of wildlife within the project area and vicinity.

Most terrestrial vertebrates range over large areas. This fact requires that information of similar type be gathered regarding adjacent areas. For example, foraging or nesting may occur within the project area, while other necessary activities may be limited to some other area. Loss of the activity areas within the project area may or may not remove the total area for one or a group of activities required by those animals within the project area and in the vicinity (perhaps within the region). Detailed studies of the vicinity or region of the project area, and a somewhat lower resolution investigation of vegetative communities (and thereby the correlated wildlife) of the vicinity and up to 50 times the maximum diameter of the area should be undertaken (if it was not during project area selection process).

The following is a theoretical (but well-founded) example of the typical terrestrial wildlife which may be encountered, given the constraints of the overall dredge spoil disposal problem in the bay area. Potential impacts are assessed and compared for significance.

Areas within the San Francisco Bay Region between Mean Higher High Water but below 60 feet above MHHW may include some fresh and brackish marshes, slough or creeks with shrubs or trees, and most comonly grasslands with minor herbs and shrubs. Assuming that the secondary constraint excluding marshes applies to fresh water marshes as well, the predominant (non-cultivated) vegetation and contained terrestrial wildlife will be that of the grassland.

Most grasslands of the bay region are not "natural" grasslands but are composed primarily of accidentally or purposefully introduced European and Asian grasses and herbs. The grasslands are frequently grazed, and ungrazed grass may be harvested for winter fodder or sold. Areas of large size (100 acres or more) suitable for material disposal will generally be of low relief and low to moderate drainage. Soils will be deep and normal soil moisture will be moderate to high throughout most of the year. Low swales or depressions of the fields will maintain higher soil moisture and may be completely innundated during the rainy season. The abundant to excessive moisture will retard many terrestrial plants and encourage local occurrences of marshland plants (salt grass and pickleweed).

Although soil and moisture conditions may provide adequate conditions for large production of food, overgrazing, excessive harvesting, or occasional cultivation may disturb a healthy cover. Herbaceous plants and shrubs (particularly salt bush, coyote bush, etc.) may invade the margins or disturbed areas of the grasslands. Overgrazing will promote colonization of herbs (especially many introduced species) and can change soil moisture balance and soil structure.

Within this context of coastal grasslands (or cultivated croplands), the composition and abundance of terrestrial wildlife will generally respond to the height of the dominant vegetation: greater height (2-3 feet rather than 1-6 inches) generally provides greater abundance and variety of species. Greater height of vegetation correlates with greater litter and humic content on and in the soil, with greater probability of additional lifeforms (shrubs and trees), and with greater habitat diversity.

Therefore, by correlation of wildlife with height or abundance of vegetation, a general assessment of the effects of construction, operation, and eventual use of a land disposal area upon the wildlife can be made quite readily. Shorter grasslands and wildlife will be less affected by disturbance, burial, and eventual use of recolonization than higher vegetation.

Greater numbers of wildlife will be affected by disposal in higher than in shorter grasslands, both in terms of species and individuals. However, because of differences in the structures of these two communities, factors other than in the short grass, ground squirrels, gophers, and some pocket mice, kangaroo rats, harvest mice, meadow voles and jack rabbits will be affected. Losses among these species, even if low in number, will indirectly diminish prey for coyotes, badgers, hawks, kites, vultures, and owls which require an open habitat for foraging. Greater vegetative height provides cover for prey species to escape most avian predators. Mammalian predators are more adapted to the chase or ambush in denser vegetation, and these may include those found in the short grasses and a greater number of carnivores (especially among the mustelids or weasels). The small mammals of high grasses will include harvest and deer mice, meadow vole, shrews, moles, and brush rabbits. Greater vegetative cover, correlated productivity, and variety of lifeforms provide shelter and food for a greater variety of birds. Greater shelter allows nest building in less exposed sites than in short grasses.

Botany

In evaluating the impacts of dredge spoil disposal on the botany of a given site, values and benefits of the existing plant communities (scientific, economic, ecological and aesthetic) must be compared with the potential values of the filled site. In an ideal dredge disposal site, the potential benefits outweigh those existing. An example would be a waste field converted to a wildlife refuge after dredge spoil disposal.

The following matrix is used to analyze the values of the existing vegetation of dredge spoil sites and other sites of possible impact. Since the criteria and values are mostly subjective, the data should not be interpreted quantitatively.

Criteria for evaluating the botanical potential of a filled area are summarized in the sample data sheet following the matrix. Some of the criteria do not easily fit into the matrix form, but this data sheet should present the needed data in a concise and easily understood form.

In assessing the impacts of terrestrial dredge spoil disposal, route of transportation (usually the pipeline route) and any areas of possible overflow must be considered in addition to the disposal site itself.

- Botanical potential of filled dredge disposal site

A. Potential for natural succession _____

1) little or none

2) colonization by introduced species likely, leading to permanent wastefield community

3) colonization by introduced species, leading to a native-dominated plant community

B. Potential for induced succession _____

1) will support native plant species if planted

2) will support introduced plant species if planted

C. Methods of improving potential

1) Addition of topsoil

2) Leeching toxic substances

3) Addition of fertilizer

4) Introduction of plants to improve soil for further succession

5) Other

D. Aesthetic potential

good fair poor

E. Potential uses of dredge spoil vegetation

	good	fair	poor
1) Wildlife habitat			
2) Agriculture			
3) Grazing			
4) Recreation			

F. Ecological potential

1) Flood control

2) Erosion control

3) Screen for unaesthetic area

	good	fair	poor
4) Noise interception			
5) Pollution filtering			
6) Gas exchange (O_2 cycling potential)			
7) Other (specify)			

• Significance of Criteria Chosen

1. Degree of modification of plant communities previous to dredge disposal.

Unmodified plant communities or those that have undergone succession to become essentially as they were before modification have the highest priority for preservation. These plant communities are significant because they are relatively rare and are most likely to support rare species and associations. The unmodified plant community represents the highest degree in the development of interrelations among organisms and between organisms and their environment. It is from these natural communities that the most information about the ecology of California can be derived, but only if they are preserved.

In highly modified plant communities, preservation is of less concern, especially if the site has been rendered unsuitable for recolonization by native or useful species. In this case, dredge spoil disposal will have a neutral or possibly even a positive effect if the resulting plant community is more useful or more aesthetically pleasing than the previous one.

Basically, in highly modified plant communities, most of the potential adverse impacts have already taken place and further modification has little further adverse effect.

2. Botanical significance. The flora should be evaluated in terms of the scientific value of the plants themselves.

a. Rare or endangered species. If any rare or endangered plants are observed or expected on the site, a priority for preservation is established. Rare and endangered species are an irreplaceable element of the California flora.

b. Species at the limits of their range can potentially provide valuable information concerning adaptation and dispersion of plants.

c. A rare plant association (two or more, often common, species existing in an unexpected combination) may be an indication of some unusual environmental condition (microclimate, soil, etc.) or an unusual plant interrelationship. Unless this association is found to be purely accidental (one species was deliberately or accidentally artificially introduced) such an association should be preserved for botanical interest.

d. The rare plant community or habitat covers a broader scope than the plant association, and in addition to its botanical significance the rare plant community is likely to support rare animal species. These rare plant communities often represent the remains of communities that were widespread in the recent past and now can, at best, be preserved as natural museums.

3. Aesthetic value.

Especially in modified plant communities an aesthetically modified plant community has higher priority for preservation than an unaesthetically modified one. For example, a park area may be artificially landscaped but it is more pleasant than a dredge disposal site. A garbage dump or junkyard, however, may actually be improved aesthetically if covered by dredge spoils and revegetated.

An unmodified plant community usually, but not always, has a high aesthetic value.

4. Existing beneficial uses of plant communities.

The existing benefits of the vegetation must be weighed in relation with the benefits of the site for dredge spoil and with the potential benefits of the rehabilitated dredge spoils. If a site is now economically or ecologically more valuable than it would be as a dredge disposal site, then it would be unsound either economically or ecologically to use it for dredge disposal.

a,b. Flood control and erosion control vegetation is often an important factor in flood and erosion control and it should be determined if modification of the plant community will increase the flood and erosion hazard. The dredge spoil containment structure, if properly constructed can often act as a flood control structure as effective as the vegetative cover, or more effective than a poor vegetative cover. Revegetation of the spoils during and after disposal can help prevent erosion.

c. Screening unaesthetic area if the present vegetation screens a visually unpleasant area it should be preserved. If a proposed dredge spoil site can potentially act as such a screen after fill and revegetation it may be a good site for that kind of land use.

d. Noise interception

Only a site with tall, dense vegetation is effective in intercepting noise, and such a site would probably be unsuitable for dredge spoil disposal for other reasons.

e,f. Pollution filtering, oxygen cycling

Vegetation is necessary to the oxygen and other essential gas cycles on earth and is one of the important factors in reducing air pollution. Its effectiveness is mainly related to leaf surface-area,

although certain plants are better pollution interceptors than others. It should be determined whether the predredge spoil community or the potential postdredge spoil community is more effective.

g. Wildlife benefits

Preservation of wildlife is one of the prime concerns of environmentalists and of anyone concerned with preservation of the environmental quality of the earth. Since wildlife is directly dependent on the plant community the existing and potential wildlife benefits of the vegetation should be considered in choosing a dredge disposal site.

h. Recreation

If present vegetation provides good recreational use (picnicing, hiking, berry picking, hunting, etc.) it is worth preserving. If a site can be improved for recreational use by revegetation of dredge spoil fill it may be a favorable site for such use.

i,j. Agricultural, grazing

Priority for preservation of agricultural and grazing land is not as high as for natural plant communities, but such land use is economically profitable and is now diminishing in quantity. With a possible food shortage it may not be wise to convert agricultural or grazing land to another type of land use. Dredge spoil disposals, however, may be suitable for some types of agriculture, and in this case the proposed land use may be favorable, especially if the existing plant communities are not of a type that has high priority for preservation.

7. AQUATIC BIOLOGY

Introduction

Aquatic biology as defined here includes any and all aquatic habitats which may be affected by the land disposal of dredge spoils. As such it will very likely include the following:

a) freshwater rivers, streams, lakes or ponds

b) brackish water shallows, including the estuaries of streams influent to San Francisco Bay

c) marine environments, taken to include areas of high salinity within San Francisco Bay

d) the biota of the aqueous phase of impounded dredge spoils subsequent to land disposal.

The aquatic biological community is a complex one, involving a large number of individuals and species that are integrated into an interdependent biological system. The characteristics of that system as observed at any given point are a product of many interrelated factors including:

1) physicochemical characteristics of the habitat, including average and extreme temperature ranges, salinity, pH, incident solar radiation and the concentration of a large number of biologically active chemical species

2) the amounts and kinds of biological loading, as influenced by the drainage area of the stream or by contribution from adjacent terrestrial habitats

3) The past history of the environment, including both natural and human related factors. The dependence of the system on past occurrences becomes generally more important when one considers the (generally larger) higher organisms with longer life-spans and more limited reproductive potential.

Minimum Baseline Information

1. Basic data from results of water quality investigation above.

2. Microbiology

   a. Planktonic species including bacteria, algae, protozoa, and permanently and transitionally planktonic forms

   b. Nektonic (free-swimming) species, including fish, aquatic insects and free-swimming invertebrates

   c. Benthic forms including the whole range of benthic organisms: protozoa and algae, lower and higher invertebrates; worms, molluscs, crustaceans, etc.; as well as benthic fish.

Plankton - The plankton investigations must be thorough enough to identify the kinds and amount of primary production which are occurring in the habitat. This information is vital in assessing the wasteload carrying capacity of the water body; the value of the site as habitat for higher organisms; currently existing pollution loads, either of total organic material or toxic wastes; the potential effect of increased biological oxygen demand such as that from organic rich dredge spoils; the potential for the biological concentration of toxic materials derived from the dredge spoils or from other sources.

Also included among the plankton are the larval stages of many species of vertebrates and invertebrates, including many species of commercially valuable fish and crabs. Examination of the plankton can identify the extent to which such larval forms are present on a seasonal basis and thus what effect, if any, can be expected with respect to adult populations as a result of human interference with planktonic populations. Planktonic

larvae are usually a more important consideration in brackish and marine habitats than in fresh water because there are in general more marine than fresh water organisms which have a planktonic stage in their life cycles.

Nekton - Included in the nekton are the vast majority of fishes, as well as some invertebrates including aquatic insects and certain crustacea. The adult stages of most commercially value fish species are included in this group; considerable attention is therefore usually paid to nektonic censuses. The baseline should contain information about the abundance and distribution of all nektonic species, with greater attention being devoted to those of commercial value and any rare or endangered forms which may be present.

The study should include consideration of both resident and transient populations. Included among the important transient species in the Bay ecosystem are the anadromous salmon, steelhead, striped bass and sturgeon. The effect, if any, of dredging operations on migratory spawning runs of these species may figure prominently in the evaluation of some potential disposal sites.

The benthic community includes those organisms which live in or on the solid substrate. Benthic populations normally include a large representation of invertebrate forms, including molluscs, crustacea and a variety of polychaete and other worms being much in evidence.

Benthic populations figure prominently in the nutrition of many nektonic species including many of commercial importance. This, coupled with the intrinsic value of the benthic community per se and its susceptibility

to damage from siltation, oxygen depletion and other factors, makes a good benthic baseline essential in any reasonable environmental study. Abundance and distribution of all well-represented species should be ascertained, specifically including polychaetes, oligochaetes, crustacea, molluscs (including micromolluscs) as well as any benthic vertebrates.

In shallow water habitats, benthic algae and vascular plants may be significantly represented. If so, their abundance and distribution should be ascertained.

In marine and brackish water habitats, the higher plants are poorly represented. Eel-grass (Phyllospadix spp.) is the only marine vascular plant of major significance. Consequently, in marine and brackish water habitats (exclusive of salt and brackish water marshes) the numerous species of both microscopic and macroscopic algae will be of major importance.

In fresh water habitats, vascular plants may play a more significant role, although in the Bay region aquatic botany may be expected to focus primarily on the highly diverse floral types included within the algae.

8. ARCHAEOLOGY

Coastal lands of Central California are known to have supported great numbers of native Americans and early European colonizers. The dependency of early peoples upon San Francisco Bay and the shallows of the outer coast for food and transportation tends to localize concentrations of archaeologic remains within zones of 1 to 5 miles from the water's edge. Within the San Francisco Bay, the intertidal and shallow subtidal areas provided shellfishes, fishes, birds, and some mammals (especially sea otter) for the tribes surrounding the Bay. However, occupation centered largely at points or prominences which extended through the marshes and provided access to open water at the point and mudflats or marshes on the side.

Prehistoric occupations originally near water's edge may be somewhat inland from their original relationship due to natural and artificial filling of the shoreline.

- Guidelines for Archaeology

1. Literature and unpublished report surveys
2. General

Location

- Distance from existing shoreline (either open water, marsh or mudflat)
- Percent of area at 20 feet above mean sea level
- Maximum relief and distance of maximum gradient to shoreline

Geology

- Area (1) Quaternary alluvium or terrace sediment

  Area (2) pre-Quaternary bedrock

  Area (3) Well-differentiated soil

  Area (4) un-differentiated (raw) soils

On-site survey by qualified archaeologist

- Black earth shell middens (typical coastal occupation indicator) on prominences

9. AESTHETICS

Aesthetic resources of a proposed project area involves the sensory qualities (appearance, odor, sound, etc.) and the potential receptors (people) who will experience these qualities. Although aware of the considerable variation of interpretation of the received sensory qualities, some basic guidelines can be derived for the study of aesthetics in relationship to the proposed projects.

<u>Guidelines</u>

Location

- Distance and direction to open water
  to highways
  to commercial or industrial units
  to airport
- Height of area above viewing points
- Relief of surface within site
- Relief of surface within 1000 feet of site perimeter

Project design

- Total area
- Perimeter length
- Levee height and relief or slope
- Number of sub units within area
- Duration of filling
- Eventual use

10. NOISE AND TRAFFIC

Introduction

In the context of the dredge spoil disposal problems noise and traffic considerations, two topics normally considered in the preparation of an EIR, may be expected to play a minimal role. The only potentially significant impacts would occur a) during construction of impoundment structures on the site and b) during actual deposition of the dredged material. There are no significant direct long-term impacts. Consequently the data requirements to establish ambient noise levels can be expected to be minimal. This statement applies equally well to the effect of the project on traffic; only during the construction phase will traffic be materially affected.

Baseline Data

In the event that baseline data for the construction phase is desired (for example, due to proximity of the proposed site to a particularly noise-sensitive installation) routine monitoring of ambient sound levels should entail few difficulties and make minimal technical demands on the analytical talents of trained personnel.

Comparison of this information with available data on noise generated by construction equipment.*

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*e.g., Noise from Construction Equipment and Operation, Building Equipment, and Home Appliances, National Technical Information Document 300.1. National Technical Information Service, Springfield, Virginia. Prepared for Environmental Protection Agency by Bolt, Beranek and Newman, December 1971.

11. PUBLIC HEALTH

Introduction

Public health considerations are pertinent to the proposed investigation for basically two reasons.

1) Associated with the dredge spoils is a finite but presently undefined health hazard which is due to the toxic metals and other substances contained in the sediment. Although the possibility of a significant public health problem arising out of this circumstance is remote, the potential seriousness of such an impact, should it occur, warrants the development of a data base adequate to place the potential risk in its proper perspective.

2) The dredge spoil disposal impoundments, particularly during and immediately after the deposition process, may constitute a physical hazard and represent an attractive nuisance. It would probably be necessary in an EIR to address this question, with particular attention being paid to the effectiveness of mitigating measures, specifically the effectiveness of measures designed to restrict access to the site during the construction and filling operations.

There is also the possibility for encouraging the growth of mosquitos in the water impounded during the initial phases of settlement. However, the high salinity of this water should largely preclude this problem.

Baseline Data

The necessary baseline information required to evaluate public health considerations can be taken from other sources previously mentioned,

particularly from the water quality and aquatic biology sections. Additional pertinent information can be derived from chemical analyses carried out on the specific sediments of a given dredge site. This data can be coupled with the results of experiments currently underway which seek to describe the chemical behavior of specific toxic materials in the context of the dredge spoil disposal problem and the chemical parameters which obtain under actual field conditions. Taken together, this information should be adequate to assess the potential for a public health problem arising out of the disposal of dredge spoils to land.

12. LAND USE

Introduction

The deposition of dredge spoil material on terrestrial sites has among other consequences a distinct effect on the ultimate suitability of the site for a variety of potential uses. The deposition of the material can result in significant changes in a number of physical parameters. Most such changes can be mitigated or significantly altered either during the active life of the disposal site or subsequent to complete utilization of its disposal capacity. The following are some of the site characteristics which are affected by the disposal operation:

(a) General elevation and natural land contours are changed.

(b) Surface water drainage patterns are altered.

(c) Permeability of the area to natural water infiltration is reduced

(d) Surface and subsurface soil characteristics are changed, influencing the potential utility of the site for agricultural, construction, or other purposes.

Because of this influence on the physical characteristics of the site, the disposal operation has at least the potential for materially influencing both public and private decisions concerning ultimate land use. For this reason, it is particularly important that the location of disposal sites be determined in such a way as to be compatible with currently existing and anticipated land use plans. By proper planning, with respect both to site location and to techniques of disposal, it may well be possible for land disposal operations to be of direct benefit to the overall socioeconomic condition of the Bay area. On the other hand, improper or inadequate planning could lead to disposal practices which were of decided detriment to the Bay community -- through the destruction of important habitat or by encouraging undesirable patterns of growth.

Baseline Data

For these reasons, expressed public policy as well as the desires and goals of concerned private groups must be thoroughly evaluated during the preparation of the environmental impact report. Detailed attention should be paid both to the specifications and implied intention of regional planning documents; such documents exist for most Bay area counties. The published policies of regulatory agencies such as the San Francisco Bay Conservation and Development Commission and organizations such as the Association of Bay Area Governments will be prime sources of information for determining public attitudes and currently mandated land use patterns.

It will be of considerable importance to contact private interest groups which are concerned with the fate of specific geographic regions as well as the public agencies which are primarily responsible for regulation of resource-related matters. For example, there are a number of groups such as the Audubon Society that are concerned with wildlife values for which the California Department of Fish and Game is primarily responsible. Such private groups not only express significant elements of private opinion, but also frequently possess valuable information concerning technical aspects of the site and the natural processes that would be affected by the project.

Mitigation Measures

The impact statement process calls for discussion of measures which could be taken to mitigate the environmental impact of the proposed project. The impacts which will have to be addressed will in part be defined in relation to extant land use plans. Once the intended use of the site is known, it will be possible to adjust filling and management procedures to maximize the compatibility of the operation with the intended ultimate use. The following is a discussion of some of the

potential ultimate uses of land disposal sites and the ways in which the disposal operation could be modified to be most compatible with that ultimate use.

Agricultural

Many of the proposed sites are currently being used for agriculture, and it may be desirable to return to agriculture after the site is filled. The following are examples of measures which might tend to facilitate a return to agricultural production:

1) During the site preparation phase, top soil could be removed and stockpiled, eventually to be spread over the spoils at the end of the project's life.

2) The characteristics of the spoils could be altered by both physical and chemical means to improve its ability to support crops. This might include mixing the spoils with certain types of solid wastes from municipal or certain industrial sources, perhaps including sewage sludge.

Open Space

Suitable open space for recreation and other purposes is in short supply in many places throughout the Bay area. The dredge spoil disposal operation could be made compatible with a variety of open space options, including park and recreation areas as well as habitat for wildlife. The suitability of a filled disposal site will again be a function of the physical effects of the disposal operation on the site. Thus it will be necessary to determine what kind of ultimate open space use is anticipated before filling procedures are begun. The homogeneity of the deposited dredged material could eventually facilitate the preparation of a variety of recreational facilities, including parks, facilities for water sports, and so on.

One advantage of the dredge disposal operation is that it is possible to derive some interim use from the site (i.e., use it for dredge spoil disposal), while at the same time assuring its availability for use at a fairly predictable date in the future. Land disposal may thus be a useful planning tool for the maintenance of open space areas if care is taken to coordinate closely with planning agencies and others with an interest in land use questions.

Engineered Fill

If filled areas were designated for eventual urban development, it is likely that the deposited spoils could be handled so that their load-bearing and other physical characteristics were optimal from an engineering standpoint. It should be borne in mind that physical properties that are desirable from an engineering standpoint may be diametrically opposed to the characteristics that would be most advantageous to agriculture. This once again points out the necêssity for advance planning with regard to the intended ultimate use of the site.

Buffer Zones

Dredge spoil disposal may have some value in creating buffer zones between otherwise adjacent incompatible uses. For example, it may be desirable to locate a disposal operation between natural wildlife areas and encroaching urban development. A positive feature of the disposal operation would be the inherent barrier to access which the disposal site represented. Further, the site may have, during the filling operation, a certain utility as wildlife habitat of marginal though perhaps significant value. Upon completion of filling, provision could be made for more permanent features to restrict or control access in perpetuity.

It should, however, be borne in mind that the compatibility of dredge spoil disposal with wildlife habitats has not been proven and should be thoroughly investigated before being undertaken. Also, creation of the buffer zone should not be made at the expense of existing wildlife habitat of high quality, such habitat already being in critically short supply.

Drainage and Erosion Control

Because of the implicit effect of the disposal program on existing land forms, there is at least the potential for using the operation to improve patterns of surface water drainage and to control runoff. It is at least conceivable that the disposal operation could be designed to control the salinity of certain wetland areas by preventing salt water intrusion during periods of low flow. This program might be integrated with plans designed to offset the effects of the Peripheral Canal should it or similar projects be implemented. It is possible that the deposition of the dredge spoil material in the Delta Island sites might help to prevent oxidation of peat deposits, thereby protecting that resource including the natural gas produced from these layers, as well as controlling the subsidence that is associated with oxidation of the peat.

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DREDGE DISPOSAL STUDY, SAN FRANCISCO BAY AND ESTUARY. APPENDIX --ETC(U)
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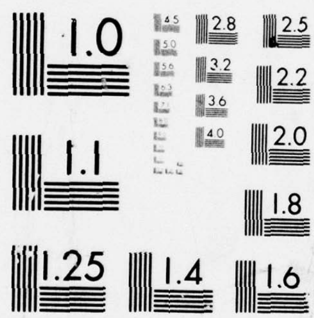

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SUMMARY

The purpose of Table 3 is to summarize the information from the foregoing listing of criteria so that a quick, rough comparison can be made of the nature of the task posed by each of the specific technical areas that must be investigated. The relative weightings are specifically applicable to the land disposal of dredge spoils on Bay area sites and represent our best professional judgment concerning the relation of each technical area to the whole.

It should be borne in mind that the numbers indicated in the table are of relative and subjective value only, and are therefore only minimally amenable to manipulation and numerical analysis.

Table 3

DEGREE OF EMPHASIS REQUIRED
IN
PREPARATION OF ENVIRONMENTAL IMPACT STATEMENTS

	DEGREE OF EMPHASIS	LEVEL OF EXPERTISE REQUIRED OF INVESTIGATOR	LIKELIHOOD OF PROBLEM (SHORT-TERM)	LIKELIHOOD OF PROBLEM (LONG-TERM)	FIELD INVESTIGATION REQUIRED
Climatology	1	3	3	1	1
Hydrology	5	5	3	1	1
Air Quality	3	5	3/5	1	3
Water Quality	5	5	3	3	5
Geology	3	3	1	1	3
Terrestrial Biology	5	5	5	5	5
Aquatic Biology	5	5	3	3	5
Archaeology	3	3	3	1	5
Aesthetics	5	5	5	3	3
Noise/Traffic	3	5	1	1	1
Public Health	3	5	1	1	1
Land Use	5	3	5	3	1

5 - Strong
3 - Moderate
1 - Minimal

APPENDIX F

BIBLIOGRAPHY

BIBLIOGRAPHY

1. U.S. Army Engineer District, San Francisco, Plan of Study - Dredge Disposal Study for San Francisco Bay and Estuary, September 1973.

2. Roberts, Charles, Environmental Dredging Characteristics, Presentation to "Planning and Engineering in the Marine Environment" short course, UCLA, July 16, 1973.

3. Sustar, John F., Dredge Material Disposal Study, San Francisco Bay and Estuary, Paper submitted for presentation to Fifth World Dredging Conference, Hamburg, June 12 - 15, 1973.

4. U.S. Army Engineer District, San Francisco, Alternative for Managing Wastewater, Summary Report, July 1971.

5. U.S. Army Engineer District, San Francisco, Project and Index Maps, River and Harbor and Flood Control, June 30, 1971.

6. Department of the Army, Office of Chief of Engineers, Analysis of Consolidated Statement of Operations, Hopper and Sidecasting Dredges, Fiscal Year 1971.

7. Comptroller General of the United States, Report to Congress - Observations of Dredging Activities and Problems - Corps of Engineers (Civil Functions) Department of the Army, May 23, 1972.

8. Huston, John, Hydraulic Dredging, Theoretical and Applied, Cornell Maritime Press, Inc., Cambridge Maryland 1970.

9. U.S. Army Engineer District, San Francisco, Hopper Dredging Practices within the San Francisco Bay Area, July 1, 1968.

10. Colorado School of Mines Research Foundation, Inc., The Transportation of Solids in Steel Pipelines, 1963.

11. Bechtel Corporation, Bulk Transport of Waste Slurries to Inland and Ocean Disposal Sites, Department of Commerce, 1969.

12. Bissell and Karn, Inc., Land Disposal of Dredge Spoils for San Francisco Bay, Prepared for the San Francisco Bay Conservation and Development Commission, 1973.

13. Dames and Moore, Feasibility and Economic Study - Land Disposal of Dredging Spoils for the San Francisco Bay Area, Twelfth Naval District, June 22, 1973.

14. San Francisco Bay Conservation and Development Commission, San Francisco Bay Plan, January 1969.

15. Association of Bay Area Governments, Regional Open Space Plan, Phase II San Francisco Bay Region, 1972.

16. Solano County, California, Resource Conservation and Open-Space Plan, Phase 2, May 1, 1973.

17. Contra Cost County Planning Department, Draft Open Space Conservation Plan, March 1973.

18. Sacramento County, California, General Plan, 1973.

19. Sacramento County, California Environmental, Conservation, and Resource Management Element, General Plan, 1973.

20. Sacramento County, California, The General Plan for the Sacramento Delta, 1964.

21. Sacramento County Zoning Code, June 6, 1972.

22. Alameda County, California, Open Space Element of the Alameda County General Plan, May 31, 1973.

23. City of Fremont, California, Open Space Element, Fremont General Plan, December 1973.

24. City of Fremont, California, Conservation Element, Fremont General Plan, 1973.

25. Santa Clara County, California, A Policy Plan for the Baylands of Santa Clara County.

26. Sonoma County, California, Flood Plain Zoning, Lower Petaluma River and Extension to Sonoma Creek (Draft), July 17, 1973.

27. City of San Jose, Alviso - Background and Recommendations, August 1973.

28. San Mateo County, California, Parks and Open Space Element, General Plan for 1990, March 25, 1969.

29. City of Redwood City, California, Land Use Element of the General Plan, December 1973.

30. City of Redwood City, California, Goals for Waterfront Development, September 1973.

31. City of Redwood City, California, Description of Waterfront Development, July 1973.

32. Wilsey and Ham, Preliminary Property Investigation and Conceptual Plan - Lands of the Flour Corporation, Ltd., Hayward, California, 1969.

33. Marin County, California, The Marin Countywide Plan, Interim Document, September 1973.

34. Napa County, California, Conservation and Open Space Element - Geneneral Plan, June 26, 1973.

35. San Francisco Bay Conservation and Development Commission, Ports, (Summary of report - "Maritime Commerce in the San Francisco Bay Area"), June 1968.

36. U.S. Army Corps of Engineers, Technical Report on San Francisco Bay Barriers, Appendix E, Barrier Plans, Geology, Soils and Construction Materials, 1963.

37. USDA Forest Service and Soil Conservation Service, Soil Survey of Sonoma County, California, 1972.

38. Pampeyan, E.H., Geologic Map of the Southern Part of Redwood Point 7 1/2 Minute Quadrangle, San Mateo County, California, San Francisco Bay Region Environment and Resources Planning Study, Basic Data Contribution, 1970.

39. Bowen, O.E., Geologic Guide to the Oil and Gas Field of Northern California, California Division of Mines and Geology Bulletin 181, 1962.

40. Goldman, H.B., Geology of San Francisco Bay, in Geologic and Engineering Aspects of San Francisco Bay Fill, California Division of Mines and Geology Special Report 97, 1969.

41. Davis, F.F. and Goldman, H.B., Mines and Mineral Resources of Contra Costa County, California Journal of Mines and Geology, Vol., 54, No.4, 1958.

42. Louderback, G.D., Geologic History of San Francisco Bay, California Division of Mines and Geology Bulletin 154, 1951.

43. Lee, C.H., and Praszker, M., Bay Mud Developments and Related Structural Foundations, in Geologic and Engineering Aspects of San Francisco Bay Fill, California Division of Mines and Geology Special Report 97, 1969.

44. Seed, H.B., Seismic Problems in the Use of Fills in San Francisco Bay, in Geologic and Engineering Aspects of San Francisco Bay Fill, California Division of Mines and Geology Special Report 97, 1969.

45. Mitchell, J.K., Engineering Properties and Problems of the San Francisco Bay Mud, California Division of Mines and Geology Special Reports 82, 1963.

46. Nichols, D.R., and Wright, N.A., Preliminary Map of Historic Margins on Marshland, San Francisco Bay, California, San Francisco Bay Region Environment and Resources Planning Study, Basic Data Contribution No. 9, 1971.

47. Brown, R.D., Jr., Faults that are Historically Active or that Show Evidence of Geologically Young Surface Displacement, San Francisco Bay Region (Miscellaneous Field Studies Map MF-331), San Francisco Bay Region & Resources Planning Study, Basic Data Contribution No. 7, 1970.

48. Treasher, R.C., Geology of the Sedimentary Deposits in San Francisco Bay, California, California Division of Mines and Geology Special Report 82, 1963.

49. Schlocker, J., Generalized Geologic Map of the San Francisco Bay Region, California, San Francisco Bay Region Environment and Resources Planning Study Basic Data Contribution 8, 1971.

50. Brown, R.D., Jr., and Lee, W.H.K., Active Faults and Preliminary Earthquake Epicenters (1969 - 1970) in the Southern Part of the San Francisco Bay Region (Miscellaneous Field Studies Map MF-307) San Francisco Bay Region Environment and Resources Planning Study, Basic Data Contribution 30, 1971.

51. U.S. Army Engineer Waterways Experimental Station, Vicksburg, Miss., Technical Report H-72-8, Disposal of Dredge Spoil, November 1972.

52. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Technical Report, Practices and Problems in the Confinement of Dredged Materials in Corps of Engineers Projects, August 1973.

53. P B Q and D, Inc., The San Francisco Bay - Delta Wastewater and Residual Solids Management Study, August 1972.

54. U.S. Army Engineer District, Charleston, Survey Report on Cooper River, S.C. Spoil Disposal, July 1966.

55. U.S. Army Engineer District, Philadelphia, Long Range Spoil Disposal Study, June 1969.

56. Port of Oakland, California, Land Disposal of Dredge Spoils from Oakland Harbor, May 25, 1972.

57. Northwestern University, Engineering Characteristics of Polluted Dredgings, March 1973.

58. Stevens, Thompson, and Runyan, Inc., Management of Dredge Spoils in Coos Bay, Oregon, January 1972.

59. Weber, W.G. Jr., Performance of Embankments Constructed over Peat, Journal of the Soil Mechanics and Foundations Divisions, ASCE, Vol., 95, No. SM 1, January 1969.

60. Duncan, J.M., and Seed,H.B., with Appendix by Ugas, C., A Study of the Feasibility of Stabilizing Delta Levees with a Berm of Composted Municipal Waste, 1973.

61. State of California, Department of Water Resources, Delta Test Levees Investigation, November 1963.

62. State of California, Department of Water Resources, Delta Levees - What is their Future?, September 1973.

63. U.S. Army, Office, Chief of Engineers, Earth and Rock-Fill Dams, General Design and Construction EM 1110-2-2300, March 1, 1973

64. Moore and Chryssafopoulos, Sample Approaches to Optimum Use of Marginal Lands, in Dames and Moore Engineering Bulletin 40, December 1972.

65. Environmental Impact Planning Corporation, The Bay Area Solid Waste Management Implementation Project, December 1973.

66. S.F. Bay Regional Water Quality Control Board, Summary Report, Interim Water Quality Management Plan, S.F. Bay Basin.

67. S.F. Bay Regional Water Quality Control, Beneficial Uses and Water Quality Objectives, S.F. Bay Basin Water Quality Control Plan,

68. Environmental Protection Agency, Great Lakes Committee on Analytical Methods, Chemistry Laboratory Manual for Bottom Sediments.

69. U.S. Army Corps of Engineers, Buffalo District, Dredging and Water Quality Problems in the Great Lakes.

70. Environmental Protection Agency, The Effects of Dredging on Water Quality in the Northwest.

71. United States Government, Department of Agriculture, Soil Survey of the Suisun Area, California, United States Government, 1934.

72. Dames & Moore, Reclamation of Hydraulic Dredged Spoil, Technical Topics, San Francisco, California.

73. Harding-Lawson Associates, Soil Investigation, Bahia Del Norte, Job No. 579.2, Black Point, Marin County, California.

74. Harding-Lawson Associates, Soil Engineering Study, Black Point Property, Job No. 202.42.

75. Harding-Lawson Associates, Soil Investigation - Day's Island, Job No. 4465,5001.01, Black Point, Marin County, California

76. Harding-Lawson Associates, Foundation Investigation - Sonoma County, Job No. 982.1.

77. Harding-Lawson Associates, Soil Investigation for PG&E Towers.

78. State of California, Division of Highways, Foundation Investigation at the Proposed Sherman Island Realignment on Road 10-SAC84, 1971.

79. State of California, Division of Highways, Foundation Investigation at the North Approach to Proposed Antioch Bridge, 1969.

80. State of California, Division of Highways, Materials Report for the Grading and Resurfacing of State Highway Route 84 in Contra Costa and Sacramento Counties, 1971.

81. State of California, Division of Highways, Boring Logs for Petaluma Bridge.

82. R.K. Miller, Memorandum Titled, Soil Test Results, Junction Point Barrier - Sherman Island - File 622.68104, 1956.

83. Salem, Abdelsalam M., and Krizer, Raymond J., Consolidation Characteristics of Dredging Slurries, Proceedings of ASCE, Vol. 99, No. WWR, November 1973.

84. Krone, R.B., Flume Studies of the Transport of Sediment in Estuarial Shoaling Processes, University of California at Berkeley Hydraulic Engineering Laboratory and SERL, 1962.

85. Vegetative Water Use, Bulletin No. 113-2, California Department of Water Resources, 1967.

86. Dredged Material Research, Miscellaneous Paper D-74-1, January 1974.

87. Gloyna, E.F., and Echerfelder, W.W., eds., Advances in Water Quality Improvement, University of Texas Press, Austin, Texas, 1968.

88. A Comprehensive Study of San Francisco Bay, 1961 - 1962, SERL Report 63-3, University of California, Berkeley.

89. Brinkhurst, R.O., The Role of Sludge Worms in Eutrophication, NTIS PB-213-894, 1972.

90. Brooks, J.L., Eutrophication and Changes in the Composition of the Zooplankton, in Eutrophication: Causes, Consequences, Correctives, National Academy Science, Washington D.C., pages 236-256, 1969.

91. Pfister, R.M., Dugan, P.R., Frea., J.I., and Randles, C.I., The Ecologic Impact of Interactions among Microorganisms and Aquatic Contaminants in Lake Erie, Phase III, Parts 5, 6 and 7, NTIS PB-216-897, 1973.

92. Rhee, G., Yull, Competition between an Alga and an Aquatic Bacterium for Phosphate, Lmnol., Oceanogr, 17(4): 505-514, 1972.

93. Turner, D.B., Workbook of Atmospheric Dispersion Estimates, Department of Health, Education and Welfare, 1969.

94. U.S. Federal Water Pollution Control Administration, Water Quality Criteria: Report of the National Advisory Committee to the Secretary of the Interior, 1968.

95. U.S. Public Health Service, Public Health Service Drinking Water Standards (Revised), 1962.

96. World Health Organization, International Standards for Drinking Water, (Third Edition), 1971.

97. Environment and Technology Assessments, Inc., Environmental Impact Assessment, a Procedure, Washington, D.C., March 1973.

98. Aynsley, E., How Air Pollution Alters Weather, New Scientist, 1969.

99. Black, J.F., and Tanny, B.L., The Use of Asphalt Coatings to Increase Rainfall, 1963.

100. Estoque, M.S., and Bhumralkar, C.M., Flow Over a Localized Heat Source, Monthly Weather Review, 1971.

101. Nakajima, C., Environmental Pollution and Climatic Change, Air Force Cambridge Res. Lab. Translation No. 101, 1973

102. Wischmeiser, W.H., and Smith, D.D., Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains, Agricultural Research Service, U.S.D.A., Handbook 282, 1965.

INCLOSURE TWO

TO

APPENDIX J

LAND DISPOSAL OF DREDGED MATERIAL
AND
ECONOMIC COMPARISON OF ALTERNATIVE DISPOSAL
SYSTEMS
DREDGED DISPOSAL STUDY SAN FRANCISCO BAY AND ESTUARY

MODEL SENSITIVITY STUDY

NOTES APPLICABLE TO SCHEMES I - VII (PAGES 3-9)

All coscs are bare. Do not include mobilization, field engineering, supervision, bonds, taxes, contingencies, overhead and profits.

ASSUMPTIONS OF COMPUTER PROGRAM

	RUN 1	RUN 2
Hourly Cost Hopper Dredge	$401.83	$506.38
Capital Cost Hopper Dredge	Existing	New
Value	$2,003,051.29	$24,000,000.00
Depreciation Period	13 years	50 years
Other Equipment	New	New
Value	See Tabulation	Page 4 - 9
Depreciation Period	20 Years	50 years
Hopper Bulking Factor	12%	25%
Hydraulic Dredge Production/Day		
16"	12,500 cy	12,500 cy
24"	25,000 cy	28,000 cy
30"	37,000 cy	44,000 cy
36"	50,000 cy	63,250 cy
Equipment Annual Use	5,000 Hrs.	6,500 Hrs.

LEGEND OF METHODS		METHOD RUN 1	METHOD RUN 2
A	Hopper/Direct Pumpout, scow, dump basin, fixed pipeline	104	57
B	18 cy Clam, bottom dump scows, dump basin, fixed pipeline	52	25
C	Hopper/Direct Pumpout, bottom dump scow	105	58
D	Hopper, bottom dump	95	48
E	18 cy Clam, bottom dump scows	54	27
F	13 cy Clam, bottom dump scows	36	18
G	13 cy Clam, bottom dump scow, dump basin, fixed pipeline	34	16
H	18 cy Clam/Scows, transfer unit, fixed pipeline	51	24
I	Hopper, transfer unit, fixed pipeline	96	49
J	Hopper/Pumpout, scow, dump basin, fixed pipeline	107	60
K	36" Hydraulic temporary pipeline	90	43
L	18 cy Clam/Scows transfer unit, temporary pipeline	48	21
M	16" Hydraulic, booster unit, temporary pipeline	61	29
N	13 cy Clam, scows, transfer unit	33	15
O	9 cy Clam, scows, transfer unit	15	6
P	18 cy Clam, bottom dump scows	54	27
Q	13 cy Clam, bottom dump scows	13	18
R	9 cy Clam, bottom dump scows	9	9
S	36" Hydraulic, booster unit, temporary pipeline	92	45
T	30" Hydraulic, booster unit, temporary pipeline	82	40
U	24" Hydraulic, booster unit, temporary pipeline	72	35
V	16" Hydraulic, booster unit, temporary pipeline	62	30
W	36" Hydraulic, booster unit, temporary pipeline	93	46
X	36" Hydraulic, temporary pipeline	90	43
Y	16" Hydraulic, booster unit, temporary pipeline	63	31
Z	36" Hydraulic, booster unit, temporary pipeline	91	44
A1	16" Hydraulic, Booster unit, temporary pipeline	56	29
B1	16" Hydraulic, temporary pipeline	55	28
C1	16" Hydraulic, temporary pipeline	60	

Scheme I: 100 Fathom Disposal Site

Dredge Site	Suisun Bay	Mare Island	Napa River *	Petaluma River *	Pinole Shoal	Ric L.
Disposal Site						100 Fath
Distance Miles	62	56	64	35	48	38
Run 1						
Least cost only #	(A) 0.74	(A) 0.66	(B) 1.17	(B) 1.28	(A) 0.62	(A)
Hopper only**	(D) 2.47	(D) 2.33			(D) 1.93	(D)
Clamshell only**	(E) 1.21	(E) 1.19	(E) 1.18	(E) 2.36	(E) 1.05	(E)
Hydraulic only**	(W) 3.78	(W) 1.91			(W) 1.87	(W)
Run 2						
Least cost only #	(A) 0.79	(A) 0.71	(B) 0.98	(B) 1.07	(C) 0.69	(E)
Hopper only**	(D) 3.47	(D) 3.28			(D) 2.72	(D)
Clamshell only**	(E) 0.88	(E) 0.90	(E) 1.18	(Q) 1.81	(E) 0.79	(E)
Hydraulic only**	(W) 3.46	(W) 1.70	(Y) 5.23	(Y) 6.01	(W) 1.64	(W)

NOTES:

See page numbers 1 & 2 for general notes and legend of dredge

*Large hydraulics and hoppers not practical at dredge site due dimensions of waterway.

#Least cost utilizing any system whether currently available, engineering and testing prior to use.

**Cost for currently available systems only equipment available presently located in the bay-area.

2

ALTERNATIVE DISPOSAL SCHEMES

aluma er	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
		100 Fathom Line						
	48	38	40	36	37	38	39	56
) 1.28	(A) 0.62	(A) 0.76	(B) 1.05	(A) 0.65	(A) 0.80	(C) 0.86	(C) 0.80	(C) 0.91
	(D) 1.93	(D) 1.95		(D) 1.48	(D) 2.01	(D) 2.15	(D) 1.98	(D) 2.46
) 2.36	(E) 1.05	(E) 0.89	(B) 1.05	(E) 0.91	(E) 0.84	(F) 0.99	(E) 0.94	(E) 1.10
	(W) 1.87	(W) 2.64		(W) 3.31	(W) 2.89	(W) 2.48	(W) 3.93	(W) 3.59
) 1.07	(C) 0.69	(E) 0.64	(B) 0.88	(E) 0.67	(E) 0.61	(E) 0.74	(E) 0.68	(E) 0.81
	(D) 2.72	(D) 2.74		(D) 2.08	(D) 2.82	(D) 3.02	(D) 2.78	(D) 3.45
) 1.81	(E) 0.79	(E) 0.69	(E) 1.50	(E) 0.67	(E) 0.61	(E) 0.74	(E) 0.68	(E) 0.81
) 6.01	(W) 1.64	(W) 2.40	(Y) 7.90	(W) 3.05	(W) 2.67	(W) 2.16	(W) 3.64	(W) 3.29

es and legend of dredge methods.

ical at dredge site due to narrow or shallow

er currently available, would require extensive

nly equipment available although not necessarily

Scheme II: Petaluma Land Disposal Site (+19¢ cu/yd)

Dredge Site	Suisun Bay	Mare Island	Napa River *	Petaluma River *	Pinole Shoal
Disposal Site					Petaluma Land D
Distance Miles	22	15	23	3	10
Run 1					
Least cost only	(A) 0.78	(A) 0.70	1.21	(L) 1.22	(I) 0.58
Hopper only**	(D) 1.36	(D) 1.16			(D) 0.84
Clamshell only**	(H) 1.20	(H) 1.24		(H) 1.24	(H) 1.10
Hydraulic only**	(S) 1.94	(S) 1.04			(S) 1.03
Run 2					
Least cost only	(A) 0.84	(A) 0.85	(B) 1.02	(H) 1.05	(I) 0.70
Hopper only**	(D) 1.74	(D) 1.47			(D) 1.03
Clamshell only**	(H) 1.01	(H) 1.02	(H) 1.15	(H) 1.05	(H) 0.93
Hydraulic only**	(S) 1.71	(S) 0.88	(V) 2.65	(V) 1.60	(S) 0.87

NOTES:

See page numbers 1&2 for general notes and legend of dredge s

*Large hydraulics and hoppers not practical at dredge site du dimensions of waterway.

#Least cost utilizing any system whether currently available, engineering and testing prior to use.

**Cost for currently available systems only equipment availab presently located in the bay-area.

ALTERNATIVE DISPOSAL SCHEMES

(+19¢ cu/yd)

Petaluma River *	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
Petaluma Land Disposal Site								
3	10	16	14	16	13	28	29	47
(L) 1.22	(I) 0.58	(A) 0.80	1.09	(A) 0.69	(I) 0.79	(A) 0.97	(A) 0.91	(A) 1.05
	(D) 0.84	(D) 1.37		(D) 1.10	(D) 1.21	(D) 1.18	(D) 1.98	(D) 2.64
(H) 1.24	(H) 1.10	(H) 1.06		(H) 1.13	(H) 1.05	(H) 1.33	(H) 1.23	(H) 1.43
	(S) 1.03	(S) 1.70		(S) 2.11	(S) 1.60	(S) 2.12	(S) 3.25	(S) 3.18
(H) 1.05	(I) 0.70	(B) 0.89	(B) 0.92	(A) 0.77	(B) 0.78	(G) 0.99	(B) 0.92	(J) 0.97
	(D) 1.03	(D) 1.75		(D) 1.39	(D) 1.54	(D) 2.87	(D) 2.60	(D) 3.50
(H) 1.05	(H) 0.93	(H) 0.99	(H) 1.21	(H) 0.95	(H) 0.87	(H) 1.09	(H) 1.00	(H) 1.16
(V) 1.60	(S) 0.87	(S) 1.49	(V) 3.42	(S) 1.99	(S) 1.41	(S) 1.83	(S) 2.98	(S) 2.90

es and legend of dredge methods.

actical at dredge site due to narrow or shallow

ther currently available, would require extensive
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s only equipment available although not necessarily

Scheme III: Sherman Island Land Disposal (+ 17¢/Cu/Yd)

Dredge Site	Suisun Bay	Mare Island	Napa River *	Petaluma River *	Pinole Shoal	Ri L.
Disposal Site						Sherman I
Distance Miles	20	29	37	48	33	45
Run 1						
Least cost only	(A) 0.91	(A) 0.83	(A) 1.34	(B) 1.45	(I) 0.71	(A
Hopper only**	(D) 1.36	(D) 1.85			(D) 1.91	(D
Clamshell only**	(H) 1.29	(H) 1.38		(H) 2.60	(H) 1.32	(H
Hydraulic only**	(S) 2.00	(S) 1.49			(S) 1.70	(S
Run 2						
Least cost only	(A) 0.96	(A) 0.87	(B) 1.14	(B) 1.23	(I) 0.83	(B
Hopper only**	(D) 1.72	(D) 2.39			(D) 2.48	(D
Clamshell only**	(H) 1.11	(H) 1.16	(H) 1.44	(H) 2.19	(H) 1.10	(H
Hydraulic only**	(S) 1.67	(S) 1.32	(V) 3.69	(V) 5.58	(S) 1.50	(S

NOTES:

See page numbers 1&2 for general notes and legend of dredge

*Large hydraulics and hoppers not practical at dredge site dimensions of waterway

#Least cost utilizing any system whether currently availabl engineering and testing prior to use.

**Cost for currently available systems only equipment availa presently located in the bay-area.

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ALTERNATIVE DISPOSAL SCHEMES

(+ 17¢/Cu/Yd)

taluma iver *	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
	Sherman Island Land Disposal							
8	33	45	44	44	42	57	57	76
B) 1.45	(I) 0.71	(A) 0.92	1.21	(A) 0.82	(I) 0.91	(A) 1.09	(A) 1.03	(A) 1.18
	(D) 1.91	(D) 2.93		(D) 2.39	(D) 2.91	(D) 3.79	(D) 3.56	(D) 4.05
H) 2.60	(H) 1.32	(H) 1.40		(H) 1.47	(H) 1.41	(H) 1.73	(H) 1.60	(H) 1.78
	(S) 1.70	(S) 3.12		(S) 3.97	(S) 3.34	(S) 3.36	(S) 5.35	(S) 4.72
B) 1.23	(I) 0.83	(B) 0.91	(B) 1.04	(A) 0.89	(B) 0.90	(G) 1.11	(B) 1.04	(J) 1.09
	(D) 2.48	(D) 3.88		(D) 3.14	(D) 3.85	(D) 5.06	(D) 4.74	(D) 5.41
H) 2.19	(H) 1.10	(H) 1.17	(H) 1.96	(H) 1.19	(H) 3.18	(H) 1.43	(H) 1.30	(H) 1.41
V) 5.58	(S) 1.50	(S) 2.87	(V) 8.76	(S) 3.68	(S) 3.09	(S) 3.00	(S) 5.02	(S) 4.38

tes and legend of dredge methods.

ractical at dredge site due to narrow or shallow

ether currently available, would require extensive
se.

ms only equipment available although not necessarily

Scheme IV: Closest Aquatic Disposal w/lowest Unit Cost

Dredge Site	Suisun Bay	Mare Island	Napa River *	Petaluma River *	Pinole Shoal	Rich L. W.
Disposal Site	Carquinez	Carquinez	Carquinez	San Pablo	Carquinez	San Pabl
Distance Miles	9	3	11	12	4	5
Run 1						
Least cost only	(C) 0.40	(D) 0.31	0.76	(E) 1.09	(D) 0.25	(D)
Hopper only**	(D) 0.45	(D) 0.31	*	*	(D) 0.25	(D)
Clamshell only**	(E) 0.76	(E) 0.79		(E) 1.09	(E) 0.69	(E)
Hydraulic only**	(W) 1.08	(X) 0.38			(Z) 0.63	(M)
Run 2						
Least cost only	(C) 0.47	(K) 0.27	(E) 0.59	(E) 0.87	(D) 0.35	(E)
Hopper only**	(D) 0.63	(D) 0.43	*	*	(D) 0.35	(D)
Clamshell only**	(E) 0.60	(E) 0.62	(E) 0.59	(E) 0.87	(E) 0.55	(E)
Hydraulic only**	(W) 0.87	(X) 0.27	(Y) 1.63	(Y) 2.10	(Z) 0.48	(Z)

NOTES:

See page numbers 1&2 for general notes and legend of dredge method

*Large hydraulics and hoppers not practical at dredge site due to dimension of waterway.

#Least cost utilizing any system, whether currently available, wou engineering and testing prior to use.

**Cost for currently available systems only equipment available al presently located in the bay-area.

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ALTERNATIVE DISPOSAL SCHEMES

ıit Cost

luma r	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
›lo	Carquinez	San Pablo	San Pablo	San Pablo	San Pablo	Alcatraz	San Bruno	South Bay
	4	5	5	7	7	7	3	3
1.09	(D) 0.25	(D) 0.45	0.66	(D) 0.37	(D) 0.52	(C) 0.54	(D) 0.27	(D) 0.31
*	(D) 0.25	(D) 0.45	*	(D) 0.37	(D) 0.52	(D) 0.70	(D) 0.27	(D) 0.31
1.09	(E) 0.69	(E) 0.62		(E) 0.70	(E) 0.65	(E) 0.85	(E) 0.70	(E) 0.69
	(Z) 0.63	(M) 0.89		(M) 1.22	(Z) 1.01	(Z) 1.06	(C$_1$) 0.63	(C$_1$) 0.48
0.87	(D) 0.35	(E) 0.49	(E) 0.52	(C) 0.47	(E) 0.50	(C) 0.63	(D) 0.38	(K) 0.41
*	(D) 0.35	(D) 0.64	*	(D) 0.52	(D) 0.73	(D) 0.99	(D) 0.38	(D) 0.43
0.87	(E) 0.55	(E) 0.49	(E) 0.52	(E) 0.55	(E) 0.50	(E) 0.66	(E) 0.55	(E) 0.54
2.10	(Z) 0.48	(Z) 0.77	(A$_1$) 1.56	(Z) 1.11	(Z) 0.84	(Z) 0.83	(B$_1$) 0.58	(X) 0.41

legend of dredge methods.

at dredge site due to narrow or shallow

urrently available, would require extensive

equipment available although not necessarily

Scheme V: Closest Seaward Aquatic Disposal Site W/Lowest Unit Cost

Dredge Site	Suisun Bay	Mare Island	Napa River *	Petaluma River *	Pinole Shoal	Richm L. W.
Disposal Site	Carquinez	Carquinez	Carquinez	San Pablo	San Pablo	Alcatr
Distance Miles	9	3	11	12	5	9
Run 1						
Least cost only	(C) 0.40	(D) 0.31	0.76	(E) 1.09	(D) 0.29	(C)
Hopper only**	(D) 0.45	(D) 0.31	*	*	(D) 0.29	(D)
Clamshell only**	(E) 0.76	(E) 0.79		(E) 1.09	(E) 0.69	(E)
Hydraulic only**	(W) 1.08	(X) 0.38			(Z) 0.66	(Y)
Run 2						
Least cost only	(C) 0.47	(K) 0.27	(E) 0.59	(E) 0.87	(D) 0.41	(E)
Hopper only**	(D) 0.63	(D) 0.43	*	*	(D) 0.41	(D)
Clamshell only**	(E) 0.60	(E) 0.62	(E) 0.59	(E) 0.87	(E) 0.55	(E)
Hydraulic only**	(W) 0.87	(X) 0.27	(Y) 1.63	(Y) 2.10	(Z) 0.51	(W)

NOTES:

See page numbers 1&2 for general notes and legend of dredge methods.

*Large hydraulics and hoppers not practical at dredge site due to n dimension of waterway.

#Least cost utilizing any sytem, whether currently available, would engineering and testing prior to use.

**Cost for currently available systems only equipment available alth presently located in the bay-area

TERNATIVE DISPOSAL SCHEMES

Jnit Cost

	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
	San Pablo	Alcatraz	Alcatraz	Alcatraz	Alcatraz	Alcatraz	Alcatraz	South Bay
	5	9	11	7	8	7	7	3
9	(D) 0.29	(C) 0.50	0.86	(D) 0.37	(C) 0.55	(C) 0.54	(D) 0.46	(D) 0.31
	(D) 0.29	(D) 0.63	*	(D) 0.37	(D) 0.57	(D) 0.70	(D) 0.46	(D) 0.31
9	(E) 0.69	(E) 0.65		(E) 0.70	(E) 0.65	(E) 0.85	(E) 0.70	(E) 0.69
	(Z) 0.66	(Y) 1.12		(M) 1.22	(Z) 1.07	(Z) 1.07	(M) 1.34	(C) 0.48
7	(D) 0.41	(E) 0.50	(E) 0.68	(C) 0.47	(E) 0.50	(C) 0.63	(E) 0.55	(K) 0.41
	(D) 0.41	(D) 0.89	*	(D) 0.52	(D) 0.80	(D) 0.99	(D) 0.65	(D) 0.43
7	(E) 0.55	(E) 0.50	(E) 0.68	(E) 0.55	(E) 0.50	(E) 0.66	(E) 0.55	(E) 0.54
0	(Z) 0.51	(W) 0.94	(Y) 2.63	(Z) 1.11	(Z) 0.90	(Z) 0.83	(Z) 1.24	(X) 0.41

d of dredge methods.

redge site due to narrow or shallow

ly available, would require extensive

ment available although not necessarily

Scheme VI: In Compliance w/C.R.W.Q.C.B. Criteria W/Lowest Unit Cost

Dredge Site	Suisun Bay	Mare Island	Napa River*	Petaluma River*	Pinole Shoal	Richm L. W.
Disposal Site	Alcatraz	100 F	100 F	Alcatraz	San Pablo	100 F
Distance Miles	33	56	64	25	5	38
Run 1						
Least cost only	(C) 0.64	(A) 0.68	1.19	(E) 1.35	(D) 0.29	(A)
Hopper only**	(D) 1.37	(D) 2.33	*	*	(D)0.29	(D)
Clamshell only**	(E) 0.89	(E) 1.19		(E) 1.35	(E) 0.69	(E)
Hydraulic only**	(W) 2.19	(W) 1.91			(Z) 0.66	(W)
Run 2						
Least cost only	(C) 0.63	(A) 0.72	(B) 0.99	(E) 1.08	(D) 0.41	(E)
Hopper only**	(D) 1.92	(D) 3.28	*	*	(D) 0.41	(D)
Clamshell only**	(E) 0.67	(E) 0.90	(E) 1.18	(E) 1.08	(E) 0.55	(E)
Hydraulic only**	(W) 1.93	(W) 1.70	(Y) 5.23	(Y) 3.21	(Z) 0.51	(W)

NOTES:

See page numbers 1&2 for general notes and legend of dredge met

*Large hydraulics and hoppers not practical at dredge site due dimension of waterway.

#Least cost utilizing any system whether currently available, engineering and testing prior to use.

**Cost for currently available systems only equipment available presently located in the bay-area.

LTERNATIVE DISPOSAL SCHEMES

nit Cost

la	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
az	San Pablo	100 F	100 F	Alcatraz	100 F	100 F	100 F	100 F
	5	38	40	7	37	38	39	56
35	(D) 0.29	(A) 0.77	1.06	(D) 0.37	(A) 0.82	(C) 0.86	(C) 0.80	(C) 0.91
'	(D)0.29	(D) 1.95	*	(D) 0.37	(D) 2.01	(D) 2.15	(D) 1.98	(D) 2.46
35	(E) 0.69	(E) 0.89		(E) 0.70	(E) 0.84	(E) 0.99	(E) 0.94	(E) 1.10
	(Z) 0.66	(W) 2.64		(M) 1.22	(W) 2.89	(W) 2.48	(W) 3.93	(W) 3.59
.08	(D) 0.41	(E) 0.64	(B) 0.89	(C) 0.47	(E) 0.61	(E) 0.74	(E) 0.68	(E) 0.81
'	(D) 0.41	(D) 2.75	*	(D) 0.52	(D) 2.82	(D) 3.02	(D) 2.78	(D) 3.45
.08	(E) 0.55	(E) 0.64	(E) 1.50	(E) 0.55	(E) 0.61	(E) 0.74	(E) 0.68	(E) 0.81
.21	(Z) 0.51	(W) 2.40	(Y) 7.90	(Z) 1.11	(W) 2.66	(W) 2.16	(W) 3.64	(W) 3.29

l legend of dredge methods

:al at dredge site due to narrow or shallow

currently available, would require extensive

.y equipment available although not necessarily

ALTERNATIVE DISPOS

Scheme VII: In Compliance W/C.R.W.Q.C.B. Criteria (Aquatic Disposal Ex/La

Dredge Site	Suisun Bay	Mare Island	Napa River *	Petaluma River *	Pinole Shoal	Ri L.
Disposal Site	Alcatraz	Petaluma	Petaluma	Alcatraz	San Pablo	Pe
Distance Miles	33	15	23	25	5	1
Run 1						
Least cost only	(C) 0.64	(A) 0.71	1.22	(E) 1.35	(D) 0.29	
Hopper only**	(D) 1.37	(D) 1.19	*	*	(D) 0.29	(D)
Clamshell only**	(E) 0.89	(H) 1.27		(E) 1.35	(E) 0.69	(
Hydraulic only**	(S) 2.19	(S) 1.04			(Z) 0.66	(
Run 2						
Least cost only	(C) 0.64	(A) 0.76	(B) 1.02	(E) 1.08	(D) 0.41	(
Hopper only**	(D) 1.92	(D) 1.49	*	*	(D) 0.41	(
Clamshell only**	(E) 0.67	(H) 1.04	(H) 1.17	(E) 1.08	(E) 0.55	(
Hydraulic only**	(W) 1.93	(S) 0.89 +19¢	(V) 2.65 +19¢	(Y) 3.21	(Z) 0.51	(

NOTES:

See page numbers 1&2 for general notes and legend of dredge met

*Large hydraulics and hoppers not practical at dredge site due dimension of waterway.

#Least cost utilizing any sytem, whether currently available, w engineering and testing prior to use.

**Cost for currently available systems only equipment available presently located in the bay-area.

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ALTERNATIVE DISPOSAL SCHEMES

(Aquatic Disposal Ex/Land Disposal In Place of 100 F Line)

etaluma iver *	Pinole Shoal	Richmond L. W.	San Rafael Cr. *	W. Richmond Channel	Richmond Harbor	Oakland Harbor	San Francisco	Redwood City
lcatraz	San Pablo	Petaluma	Petaluma	Alcatraz	Petaluma	Petaluma	Petaluma	Petaluma
25	5	16	14	7	13	28	29	47
(E) 1.35	(D) 0.29	0.80	1.09	(D) 0.37	(I) 0.79	(A) 0.97	(A) 0.91	(A) 1.06
*	(D) 0.29	(D) 1.40	*	(D) 0.37	(D) 1.21	(D) 2.22	(D) 2.12	(D) 2.62
(E) 1.35	(E) 0.69	(H) 1.10		(E) 0.70	(H) 1.08	(H) 1.36	(H) 1.27	(H) 1.46
	(Z) 0.66	(S) 1.70		(M) 1.22	(S) 1.60	(S) 2.12	(S) 3.25	(S) 3.18
(E) 1.08	(D) 0.41	(B) 0.79	(B) 0.73	(C) 0.47	(B) 0.59	(G) 0.43	(B) 0.92	(J) 0.98
*	(D) 0.41	(D) 1.77	*	(D) 0.52	(D)1.56	(D) 2.89	(D) 2.62	(D) 3.52
(E) 1.08	(E) 0.55	(H) 0.91	(H) 1.23	(E) 0.55	(H) 0.89	(H) 1.11	(H) 1.02	(H) 1.18
(Y) 3.21	(Z) 0.51	(X) +19¢	(Y) +19¢	(Z) 1.11	(S) 1.41 +19¢	(S) 1.83 +19¢	(S) 2.98 +19¢	(S) 2.90 +19¢

and legend of dredge methods.

ical at dredge site due to narrow or shallow

r currently available, would require extensive

nly equipment available although not necessarily